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The Journal of
Bone and Joint Surgery

FLEXOR-TENDON GRAFTS TO THE FINGER AND THUMB *

BY WALTER C. GRAHAM, M.D., SANTA BARBARA, CALIFORNIA

The loss of the flexor tendon to a finger or thumb handicaps greatly the function of the hand. When the flexor tendons have been cut, there is loss of both the pinch and hook mechanisms of the fingers, as well as of the ability to grasp and to hold objects. It is obvious that the most logical treatment is a restoration of the flexor-tendon function to the finger or thumb. When a flexor tendon has been cut for some time, the proximal end will retract into the palm of the hand, so that it is impossible to do an end-to-end anastomosis. Any excess scar through which the tendon glides will inhibit function of the tendon, unless it is completely excised and replaced by healthy, viable tissue. There is no reason to attempt to restore flexor-tendon function to a finger which has no sensation, because there is a tendency for the patient to substitute a finger with normal sensation in preference to using the one which has been grafted. To restore function to a finger requires a tremendous effort on the part of the patient, and he must use the finger to recover the tendon action. The following views relating to this problem are based upon experiences gained in 141 flexor-tendon grafts. The methods advocated have been found to yield gratifying results in suitable cases.

A great deal of work to produce tendon sheaths has been done by Mayer, Thatcher, and Ransohoff, by inserting various materials through the fingers to produce a gliding surface for the tendon. We have not attempted this method, as we felt that Nature would restore a sheath, if a moving tendon could be produced. It is our feeling that the pulleys are extremely important to prevent bowstringing of the tendon, and that the graft should be threaded through. A pulley should not be cut to form a sheath for the tendon. It is also extremely important that the tendon should not pass over exposed bone, as it would certainly adhere. A grafted tendon should have considerable freedom in the sheath, as there is appreciable swelling of the graft during the healing stage, and a tight sheath would tend to strangle the graft and produce necrosis and adhesions.

Not all fingers with lacerated tendons are amenable to grafting. The primary consideration should be given to sensation. In addition, there is no hope of restoring flexor-tendon function to a finger that is excessively scarred. It is preferable to do an arthrodesis at the distal interphalangeal joint, and a tendon graft only as far as the middle joint. The little finger is the most difficult in which to restore flexor-tendon function with a graft. Few people realize that this finger is used very little in the ordinary function of the hand, with the exception of operating a machine, such as a typewriter, or playing a musical instrument. In patients whose occupations require the use of such instruments, a graft is indicated. As a rule, the sublimis tendon is excised and the profundus tendon assumes the

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1947.

FIG. 1-A

FIG. 1-B

FIG. 1-C

FIG. 1-D

Fig. 1-A: Original photograph of hand in flexion. Patient has loss of flexor tendon to the index finger.
Fig. 1-B: Tendon is stuck in sheath.
Figs. 1-C and 1-D: Range of tendon function after flexor-tendon graft with blocking of median nerve and forceful active freeing of tendon. The palmaris longus was used as a graft.

control of the distal two joints of the finger. There is a tendency for the proximal interphalangeal joint to go into hyperextension, if the sublimis tendon is excised too far distally. This tendency can be controlled by fixing the stump of the sublimis tendon across the proximal interphalangeal joint into the proximal phalanx, with the joint held in about 10 degrees of flexion. It has been suggested by John R. Moore that, in highly specialized personnel, where the laceration is distal to the proximal interphalangeal joint, the sublimis function can be retained and a graft can be extended to the distal phalanx and fixed proximally to the stump of the profundus tendon, thus restoring the intricate mechanism of the finger. This method has proved very satisfactory. It is obvious that a flexor-tendon

graft should not be attempted on a finger which has any stiffness of the joints. The finger joints should move as freely as those of a normal finger before a graft is attempted. An effort should also be made to restore the muscle tone, as it is extremely important that sufficient motor power be present to mobilize the tendon through the sheath.

There are many donor sites from which one may secure a graft. The most accessible is the tendon of the palmaris longus, when present. This tendon should be dissected out so that the gliding surface surrounding the tendon will also be transplanted, as mobilization will thus be made simpler. If both the sublimis and profundus tendons have been lacerated, the sublimis tendon may be used as a graft. It is wise to fix the proximal stump of the sublimis into the profundus tendon, thus giving added motor power to the finger. The long extensor tendons of the second, third, fourth, and fifth toes are also available

FIG. 2-A

FIG. 2-B

Fig. 2-A: Loss of flexor tendon to little finger is shown.
Fig. 2-B: Shows extension of hand after treatment by flexor-tendon graft.

FIG. 2-C

FIG. 2-D

Photographs show postoperative function.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Shows loss of portion of fingers and thumb and of the flexor tendon to the little finger. Because parts of each of the other digits had been destroyed, the graft was applied to the little finger.
Fig. 3-B: Photograph shows extension possible after operation.

FIG. 3-C

Amount of flexion is shown.

for grafts. These tendons are usually not so desirable, because they have a tendency to fray. The peronaeus longus or the tendon of the plantaris muscle may be used, but one must bear in mind that a tendon which is too large will become necrotic in the center and produce more local reaction. In addition, it has a tendency to adhere to the sheath. Occasionally a tendon from another individual has been used, and has proved satisfactory.

The site of suturing a tendon graft is extremely important. The suture line should never be between the proximal interphalangeal crease and the distal palmar crease. Distally, the graft may be sutured to the stump of the profundus tendon or into the distal phalanx at the original insertion of the profundus tendon. Proximally, the suture line should be located in the base of the palm or above the wrist.

The procedure of flexor-tendon grafting first includes excision of scar tissue and of the stump of the old tendon. In many cases, flaps are required to replace badly scarred areas. The distal and proximal stumps of the lacerated tendon are freed with a tendon stripper. It is desirable to excise the distal portion of the stump and to thread the graft through the pulleys, thus eliminating the tendency for a few tendons to become bowstrung. We have had better success when the graft is fixed distally by the Bunnell technique with pull-out wire. Attempts to thread sutures back and forth through a short stump distally have proved unsatisfactory. Proximally, either the Bunnell technique with pull-out wire may be used, or an end-to-end suturing with silk may be done. The silk technique, as described by Bunnell, has proved satisfactory, the suture line being wrapped with the sheath of the lumbricalis. In a flexor-tendon graft to the thumb, the graft is fixed distally with a pull-out wire, and the proximal suture line is well above the wrist. If there is extreme scarring

FIG. 4-A

FIG. 4-B

Flexor tendon of thumb has been lacerated through the thenar eminence. Photographs show function of the tendon following flexor-tendon graft.

in the base of the palm, threading of the tendon outside of the carpal canal may be done.

On many occasions, it is desirable to substitute a muscle from another finger for the motor power. This is particularly true in lacerations of long standing, when advanced atrophy of the muscle is secondary to the laceration. The sublimis tendon of the ring finger may be used as motor power for the index finger, middle finger, or thumb, when there is

FIG. 5-A

FIG. 5-B

The flexor tendon of the thumb has been completely lacerated, with marked scarring. Final photographs reveal function. (The flexor tendon has been transplanted subcutaneously to avoid scarred areas.)

FIG. 6-A

FIG. 6-B

FIG. 6-C

Fig. 6-A: Original photograph of hand in flexion, after loss of profundus tendon to middle finger, the sublimis tendon being intact.

Figs. 6-B and 6-C: Show flexion and extension after flexor-tendon graft to restore profundus action.

marked atrophy or damage to their natural muscles. This muscle switching can be carried out as indicated, without jeopardizing the function of the finger. A period of muscle exercises and training prior to the tendon-grafting is very desirable and helpful, when the laceration is of long standing, and may eliminate the necessity of switching a muscle.

The most important part of flexor-tendon grafting comes after the surgery has been completed. It is our policy to splint the hand and wrist for a period of twenty-one days; following that, the splinting is removed and moderate active motion and full passive motion are instituted, care being taken not to extend the fingers fully. After four weeks, moderate resistive exercises are instituted; and in six weeks, flexion against resistance is encouraged. The technique of freeing the flexor-tendon graft in its newly formed sheath is extremely important. Each joint should be held individually, and forceful active flexion should be encouraged. Forceful extension is also necessary to prevent fixed flexion contractures. This should not be done in less than six weeks, as there is danger of tearing the distal attachment of the tendon. In practically all instances, a snap will be felt as the tendon is freed in the sheath; and an increase in the flexion function will be noted

FIG. 7-A

FIG. 7-B

FIG. 7-C

Fig. 7-A: Original photograph of hand in flexion shows lacerated flexor tendon to the ring finger and middle finger in a child of six years.

Figs. 7-B and 7-C: Show function six months after tendolysis of previously sutured tendon to little finger and flexor-tendon graft to ring finger.

immediately. If the function of a graft has not been restored in eight weeks, the prognosis is discouraging.

Operative tendolysis by stripping the tendon after six or seven weeks frequently will restore considerably more function. The operative incision should be above the wrist, and the tendolysis should be carried out with a tendon stripper so that immediate active mobilization of the fingers can be instituted. On occasions, the distal attachment of a flexor graft will pull loose, and it is our feeling that a re-grafting should be done immediately. The results from immediate re-grafting have been extremely gratifying, and this procedure should be considered on all occasions in which the graft pulls loose, either distally or proximally. Frequently a patient will be reluctant to put sufficient flexor pull on a tendon to free the adhesions along the sheath, because of pain in the hand. We have found it quite helpful to block the median or the ulnar nerve and to promote flexion in the anaesthetized finger. Often a graft which is not functioning will be restored to almost 90 per cent. of function by this simple procedure. Hand blocks, as described by Bunnell, are used continuously after the fourth week. It is our feeling that occupational therapy is extremely helpful in restoring flexor-tendon function, and we have encouraged this type of mobilization of a tendon.

CONCLUSIONS

1. In a severely scarred finger, fusion of the distal interphalangeal joint is frequently preferable to an attempt to restore flexor-tendon function. If the finger has good sensation and good joint function, a flexor-tendon graft will restore useful function.

2. The graft should be dissected out, to retain the gliding material on the tendon.

3. The restoration of function requires constant effort on the part of the operator in the form of encouragement and personal supervision of the mobilization of the tendon.

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TENDINOUS RECONSTRUCTION OF THE HAND FOLLOWING IRREPARABLE INJURY TO THE PERIPHERAL NERVES AND BRACHIAL PLEXUS *

BY MAJOR C. A. LUCKEY AND CAPTAIN S. R. MCPHERSON

Medical Corps, Army of the United States

Wounds incurred in combat have produced a variety of nerve lesions in the upper extremity. Besides injuries at various levels to the radial nerve, the median nerve, and the ulnar nerve, combined involvement of the median and ulnar nerves was also common. Injuries to the brachial plexus, either complete or partial, were produced frequently. In addition to these involvements of the main trunk, many cases were seen of damage to the nerves to one or several muscles of the forearm and hand. Frequently, normally functioning hands were seen with paralysis of only one muscle, — for example, the extensor pollicis longus, the flexor pollicis longus, the first dorsal interosseus, or the flexor digitorum profundus tendon of the index finger.

This paper deals only with the reconstruction of motor function in irreparable nerve injuries. In addition to those cases in which the nerve or nerves could not be sutured, it also includes cases in which the nerves were sutured, but function returned only partially or not at all.

Before tendon transplantation can be carried out, several conditions must exist.

1. *The joints to be activated should be limber.* Stiff joints are conducive to failure of the procedure.

2. *A satisfactory muscle and tendon should be available for transplantation.* In some cases of extensive paralysis, one may have to use a tendon, the muscle of which had been paralyzed but has recovered. If recovery is only partial, excellent results should not be anticipated. However, sometimes there is no choice and one has to use an incompletely recovered muscle. When there is a choice of muscles, that one should be used whose tendon has a range of excursion which most nearly equals that of the dysfunctioning tendon.

3. *Scar tissue in the path of the transplant should be excised.* If scar tissue is always excised before transplantation, the insertion of tubes to form tendon sheaths for the transplanted tendons is seldom necessary. One cannot transplant a tendon through scar tissue and expect gliding of that tendon.

Light adhesions will form along the tendon whether or not mesothelial-lined channels have been formed beforehand, since these small fibrous strands carry small blood vessels and are instrumental in revascularization of the tendon. These adhesions must either be broken down or elongated, or both, by active use of the tendon after healing has taken place.

The early work done by Biesalski and Mayer has served as a stimulus to tendon surgery. Their work on the anatomy and physiology of tendons, together with the surgical techniques they fostered, has been responsible, to a great extent, for the progress made in the field of tendon surgery.

RESTORATION OF FUNCTION TO AN INDIVIDUAL MUSCLE

Loss of function due to damage of an individual muscle can frequently be restored, since usually there will be a choice of muscles to use.

On several occasions, the first dorsal interosseus has been the only muscle paralyzed by a wound through the palm. Its action can be restored readily by transplanting the

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extensor indicis proprius into the tendinous expansion of the first dorsal interosseus (Figs. 1-A, 1-B, and 1-C). This procedure is also used by Bunnell[5] to restore abduction of the index finger in irreparable paralysis of the ulnar nerve.

The action of the extensor pollicis longus is restored by transplanting the extensor indicis proprius[6] or the extensor carpi radialis brevis (or the extensor carpi radialis longus) into the extensor pollicis longus tendon (Figs. 2-A, 2-B, 2-C, 3-A, 3-B, and 3-C). If the extensor pollicis longus is only paralyzed and no damage has been done to its tendon, the extensor carpi radialis transplant should be proximal to the wrist. This preserves the oblique pull around Lister's tubercle. In restoration of function to the extensor pollicis longus, one must strive to get the thumb and its metacarpal extended actively in the plane of the palm. With the proper tension and by pre-

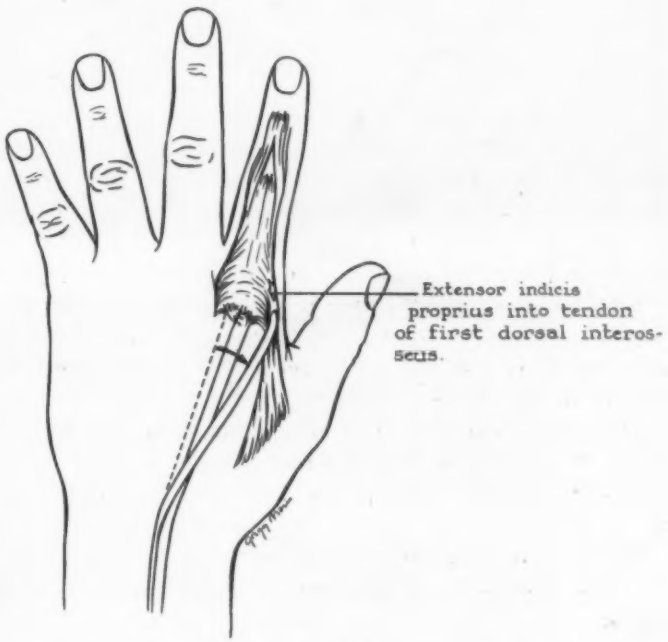

FIG. 1-A

Procedure devised by Bunnell for paralysis of first dorsal interosseus. Extensor indicis proprius is transplanted into tendon of first dorsal interosseus.

FIG. 1-B

FIG. 1-C

Fig. 1-B: Preoperative photograph shows adduction of long finger, ring finger, and little finger, but no abduction of index finger.

Fig. 1-C: Photograph taken after operation shows abduction of index finger.

FIG. 2-A

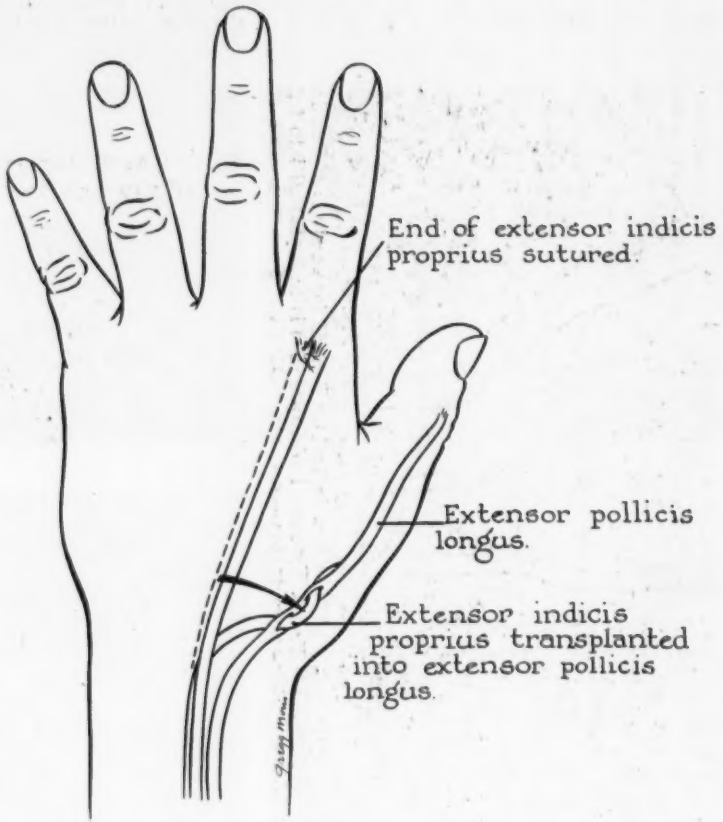
End of extensor indicis proprius sutured.
Extensor pollicis longus.
Extensor indicis proprius transplanted into extensor pollicis longus.

FIG. 2-B

FIG. 2-C

Fig. 2-A: Preoperative photograph shows limitation of extension of thumb.
Fig. 2-B: Commonly accepted procedure in paralysis of extensor pollicis longus. Extensor indicis proprius is transplanted into extensor pollicis longus.
Fig. 2-C: After operation, thumb can be extended.

Fig. 2-B: Commonly accepted procedure in paralysis of extensor pollicis longus. Extensor indicis proprius is transplanted into extensor pollicis longus.
Fig. 2-C: After operation, thumb can be extended.

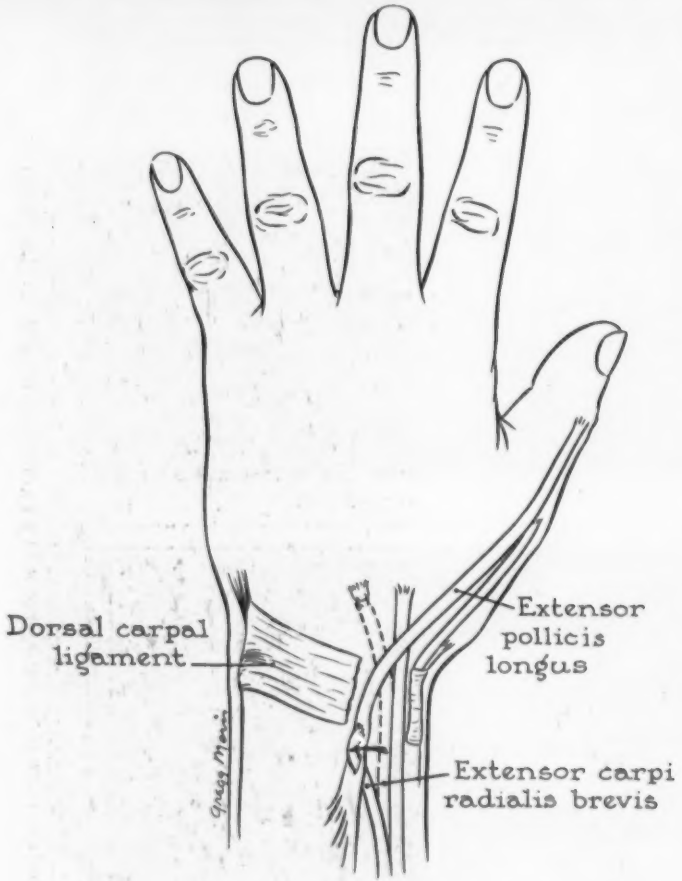

FIG. 3-A

FIG. 3-B

FIG. 3-C

Fig. 3-A: When the extensor carpi radialis brevis is used to restore activity of the extensor pollicis longus, the transplantation should be done proximal to the dorsal carpal ligament, if possible. This retains the oblique pull around Lister's tubercle.
Figs. 3-B and 3-C: Postoperative photographs show range of motion of the thumb.

serving the oblique pull around Lister's tubercle, this can be accomplished. The distal phalanx usually can be extended weakly by the extensor pollicis brevis. The extensor indicis proprius has a greater range of excursion than the wrist extensors; therefore, the authors prefer the extensor indicis proprius when doing the transplantation. The tension of these transplants must be watched closely. If they are too lax, they do not restore the desired action. If they are too snug, the thumb can be

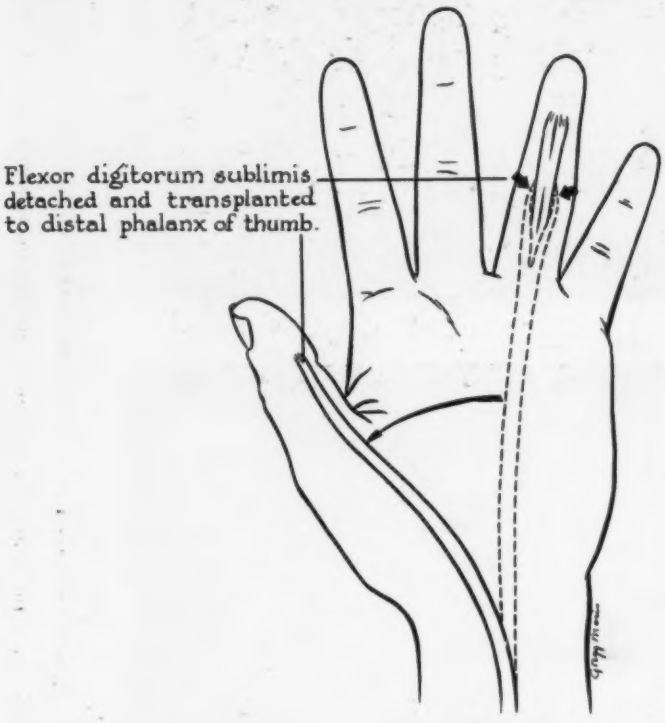

FIG. 4-A

Fig. 4-A: For destruction of flexor pollicis longus and its tendons, the flexor digitorum sublimis of the ring finger is detached from its insertion and transplanted to the distal phalanx of the thumb. This procedure gives complete range of flexor activity of the thumb. If the ring finger does not have a good flexor profundus and sublimis, one of the procedures to be described subsequently should be employed. If the flexor pollicis longus tendon is intact, the transplantation should be done at wrist level.

FIG. 4-B

FIG. 4-C

Fig. 4-B: Postoperative photograph, showing range of flexion of thumb.
Fig. 4-C: Showing complete extension of thumb, after operative procedure described in Fig. 4-A.

FIG. 5-A

FIG. 5-B

FIG. 5-C

Fig. 5-A: Preoperative photograph of hand with paralysis of flexor pollicis longus.
Fig. 5-B: Procedure for correcting paralysis of flexor pollicis longus. The palmaris longus is transplanted into the tendon of the flexor pollicis longus. In median-nerve paralysis with incomplete recovery (poor return, or none, in the flexor pollicis longus), this procedure can be used, or the flexor carpi radialis, if functioning normally, can be used as a transplant.
Fig. 5-C: Shows hand after procedure described in Fig. 5-B has been carried out. Flexion of the thumb is not complete, due to limited range of palmaris longus.

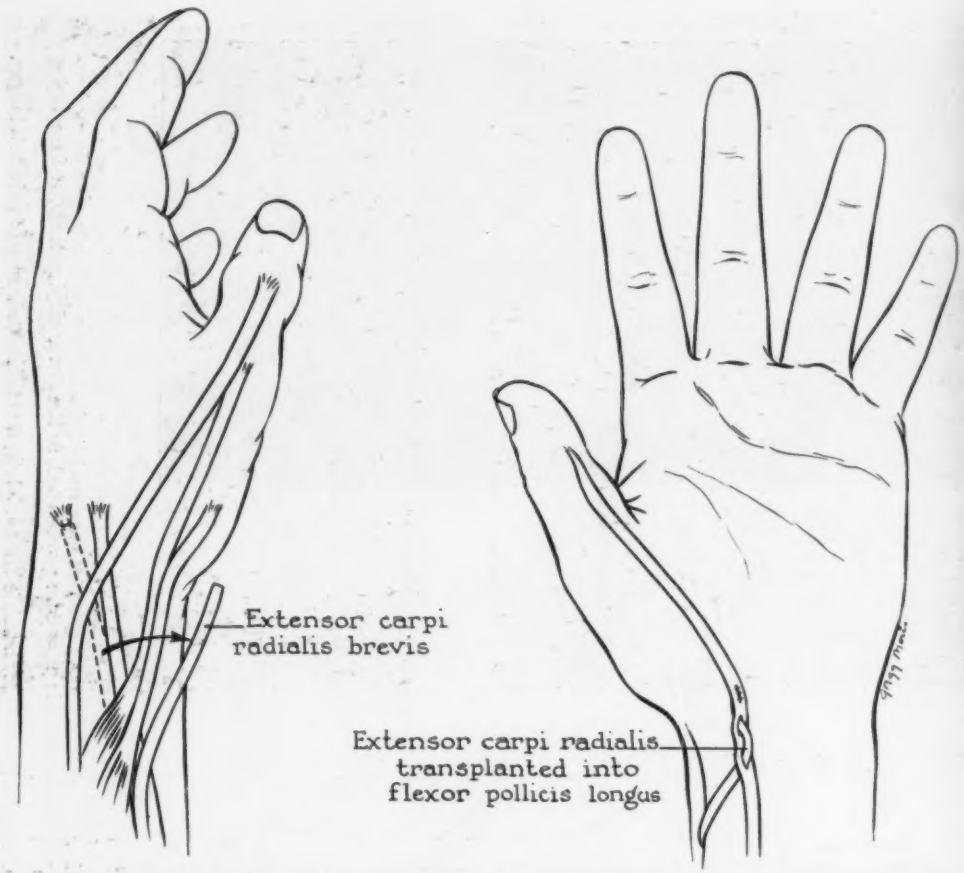

FIG. 6-A

For paralysis of the flexor pollicis longus, the extensor carpi radialis brevis is transplanted into the flexor pollicis longus. Good results are obtained when extensors are transplanted into flexors, because of their synergistic action.

lifted satisfactorily, but it cannot be brought across the palm well.

Loss of action of the abductor pollicis longus and the extensor pollicis brevis brings the thumb next to the metacarpal of the index finger. This close relationship between the thumb and the index finger interferes with the grasping of objects[6]. Transplantation of the extensor carpi radialis brevis into the tendons of these two muscles produces excellent results. If one of the radial extensors of the wrist is not available, the palmaris longus can be used, as is done routinely in transplantation for radial-nerve paralysis. Tension on these transplants will seldom, if ever, be excessive. As a rule, we should attempt to transplant extensors to flexors and flexors to extensors [14]. However, when this is not possible, flexors can be transplanted into flexors and extensors into extensors, with good results.

The flexor pollicis longus is sometimes the only muscle paralyzed. Direct trauma may also destroy the tendon of this muscle. Suture of a high median-nerve lesion frequently will bring about a return of function in the long finger flexors and wrist flexors, and a return of sensation. Return of intrinsic-muscle function is usually negligible, or not present at all. In addition, flexor pollicis longus action in many instances is minimum, even when the maximum time has elapsed after nerve suture. If only the flexor pollicis longus is paralyzed, a number of possibilities exist for restoration of its function. In view of the long range of excursion of this tendon, a tendon and a muscle of equal excursion should be used, whenever possible.

The only tendons with excursion sufficient to carry the thumb through a full range of motion are the flexor digitorum sublimis and the flexor digitorum profundus tendons;

FIG. 6-B

FIG. 6-C

Fig. 6-B: Shows hand before operation.
Fig. 6-C: Amount of flexion possible after operative procedure described in Fig. 6-A has been carried out.

but the flexor digitorum profundus tendons should not be sacrificed. If the tendon of the flexor pollicis longus is also damaged, the procedure shown in Figure 4-A should be employed. If the flexor pollicis longus tendon is intact, and only the muscle is paralyzed, the flexor digitorum sublimis of the ring finger should be detached proximal to the flexor tunnel; and the proximal end of the distal segment should be sutured to the flexor digitorum sublimis of the long finger. The distal end of the proximal segment should then be transplanted to the flexor pollicis longus. This restores full flexion of the thumb. If the flexor digitorum sublimis tendons are functioning poorly, as the result of a median-nerve injury with only partial recovery, or if the flexor digitorum profundus of the finger under consideration is not working well, some other tendon should be used.

The palmaris longus (Fig. 5-B), the flexor carpi radialis, the wrist extensors, or the brachioradialis may be used, but their range of excursion is less than that of the flexor pollicis longus. According to Bunnell, the wrist tendons have a range of approximately one and one-quarter inches, while the flexor pollicis longus has a range of about two and one-quarter inches. Full flexion of the thumb is not regained in these cases; therefore, the thumb should be in slight flexion when the tendon is sutured. There will be some limitation of thumb extension if the transplantation is done with the thumb in slight flexion; however, it is more important to obtain adequate active flexion of the thumb than full extension.

The extensor carpi radialis longus or the extensor carpi radialis brevis can be used most advantageously, because of their synergistic action with the flexors [14]. Here the transplanted tendon should also be sutured with the thumb in slight flexion, since the range of excursion of the wrist extensors is no greater than that of the wrist flexors (Fig. 6-A). In cases in which the radiocarpal joint has been arthrodesed, the wrist flexors and extensors are more suitable for transplantation, since all the motion then is in the joint of the thumb and none is taken up by a mobile wrist.

Loss of individual action of the flexor digitorum profundus can be restored by suturing

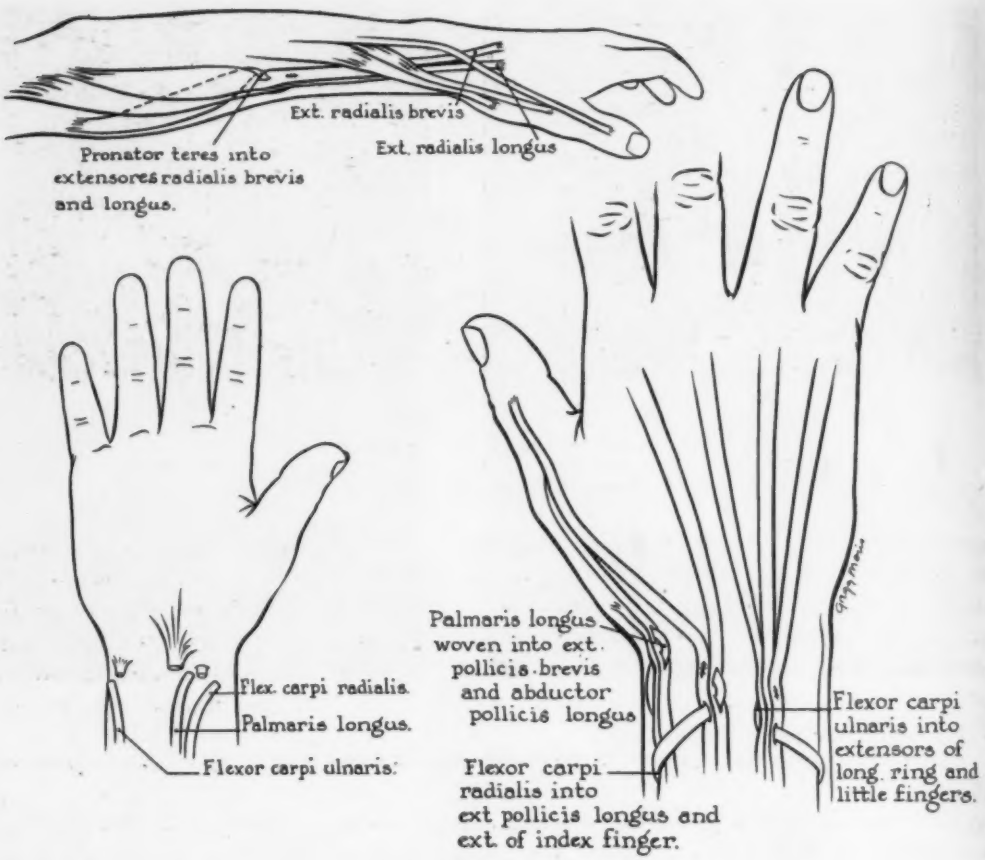
Ext. radialis brevis
Ext. radialis longus
Pronator teres into extensores radialis brevis and longus.
Flex. carpi radialis.
Palmaris longus.
Flexor carpi ulnaris.
Palmaris longus woven into ext. pollicis brevis and abductor pollicis longus
Flexor carpi radialis into ext pollicis longus and ext. of index finger.
Flexor carpi ulnaris into extensors of long, ring and little fingers.

FIG. 7-A

Procedure used for correcting irreparable paralysis of radial nerve:
1. Flexor carpi radialis is transplanted into extensor pollicis longus and extensor of index finger.
2. Flexor carpi ulnaris is transplanted into extensor tendons of long finger, ring finger, and little finger.
3. Palmaris longus is transplanted into abductor pollicis longus and extensor pollicis brevis.
4. Pronator teres is transplanted into extensor carpi radialis longus and extensor carpi radialis brevis.

The transplanted flexor tendons, as shown, extend too acutely. Their line of pull is considerably straighter than shown here.

FIG. 7-B

FIG. 7-C

Show extension and flexion possible after operative procedure described in Fig. 7-A.

the dysfunctioning tendon to the adjacent functioning profundus tendon, or by utilizing an adjacent active sublimis tendon, as recommended by Stiles and Forrester-Brown.

RADIAL-NERVE PARALYSIS

Tendinous reconstruction for permanent paralysis of the radial nerve gives good results. The authors have used the method advocated by Sir Robert Jones, with slight

FIG. 8-A

FIG. 8-B

Fig. 8-A: Before transplanting tendons for radial-nerve paralysis.
Fig. 8-B: After tendon transplantation. All the large veins have been retained. Subcutaneous fat covers the transplants. Wire has been used for tendon approximation.

modifications. The pronator teres is transplanted into the extensor carpi radialis longus and the extensor carpi radialis brevis. The flexor carpi ulnaris is transplanted into the extensor tendons of the long finger, the ring finger, and the little finger. The flexor carpi radialis is transplanted into the extensor pollicis longus and the extensor of the index finger (common extensor or extensor indicis proprius). The palmaris longus is transplanted into the abductor pollicis longus and the extensor pollicis brevis, as recommended by Bunnell (Figs. 7-A, 7-B, and 7-C).

If a transplantation is not made into the long abductor of the thumb, the thumb may ride too close to the index finger. In the absence of a palmaris longus, the authors transplant the flexor carpi radialis through the abductor pollicis longus, and then into the extensor pollicis longus and the extensor of the index finger. In spite of the difference in range of excursion of the thumb abductor and extensor, the results have been satisfactory.

Several points should be observed for optimum results. The pronator teres is transplanted through a separate incision. The authors have found that all three of the flexor tendons of the wrist can be detached and transplanted through one dorsal L-shaped incision. Through this approach, the tendons can readily be stripped back far enough by sliding curved scissors down along the tendon and muscle, and cutting all the fascial bands to permit a straight line of pull. When the L-shaped flap is being elevated, only the skin is lifted, and the veins and fatty layer are left intact. If the tourniquet is inflated soon after the arm has been elevated, and no constricting bandage is applied to empty the veins prior to inflation of the tourniquet, the veins will stand out and can easily be avoided. Two longitudinal incisions are then made through the fatty layer, and the transplantations are carried out. The layer of subcutaneous fatty tissue is then sutured together over the tendons. Thus normal fatty tissue surrounds the tendons,—a condition conducive to proper gliding of the tendons. Altman and Trott state that they have discarded dorsal L-shaped incisions because of postoperative oedema of the hand and sloughing of the corner of the L-shaped flap. The authors have not experienced either complication. We feel that preservation of the dorsal veins and the subcutaneous fat prevents postoperative swelling of the hand, and provides good gliding material around the site of the transplants (Figs. 8-A and 8-B). Sloughing at the corner of the incision can be avoided by cutting a rounded corner and by handling the flap gently. This flap is similar to a pedicle graft and, if cut and handled in a like manner, trouble will be averted.

The transplantations should be carried out with sufficient tension. Seldom will a radial transplant be too tight; on the other hand, it can be too lax. One of the authors' patients was operated upon elsewhere, and insufficient tension was put upon the tendons.

No function was obtained from the transplant. After shortening of the already transplanted tendon was carried out by the authors, the patient obtained excellent results. Some surgeons advocate wrist fusion for radial-nerve paralysis. There is some instability of the wrist as the result of transplanting all the wrist flexors [13, 15]. Arthrodesis can be

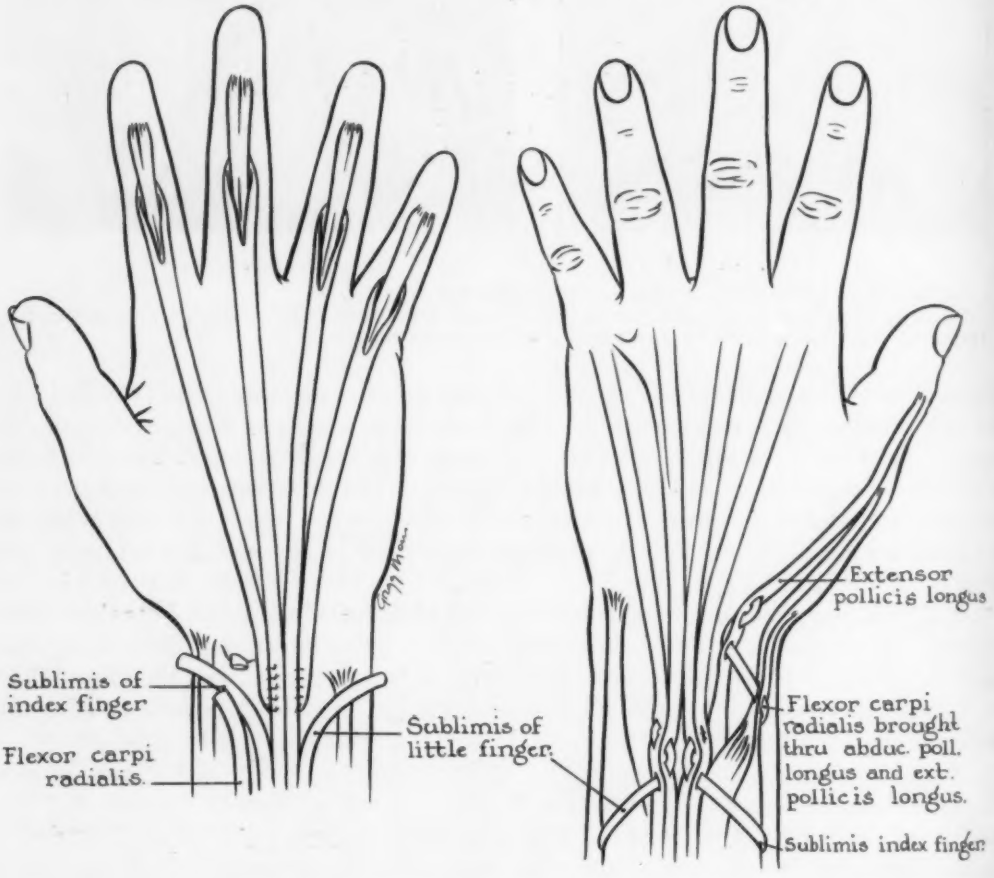
Sublimis of index finger
Flexor carpi radialis
Sublimis of little finger
Extensor pollicis longus
Flexor carpi radialis brought thru abduc. poll. longus and ext. pollicis longus.
Sublimis index finger

FIG. 9-A

Another procedure used in correction of irreparable paralysis of the radial nerve is the following:

1. Sublimis of little finger and of index finger severed at wrist; proximal end of distal segment is sutured to adjacent sublimis tendons.
2. Sublimis of little finger transplanted to extensors of little finger and ring finger.
3. Sublimis of index finger transplanted to extensors of index finger and long finger.
4. Flexor carpi radialis transplanted to extensor pollicis longus and extensor pollicis brevis, and to abductor pollicis longus.

This procedure is not advocated, because the sublimis tendons are too short to be transplanted posteriorly.

FIG. 9-B

FIG. 9-C

Show flexion and extension obtained after operative procedure described in Fig. 9-A. Extension is not sufficient.

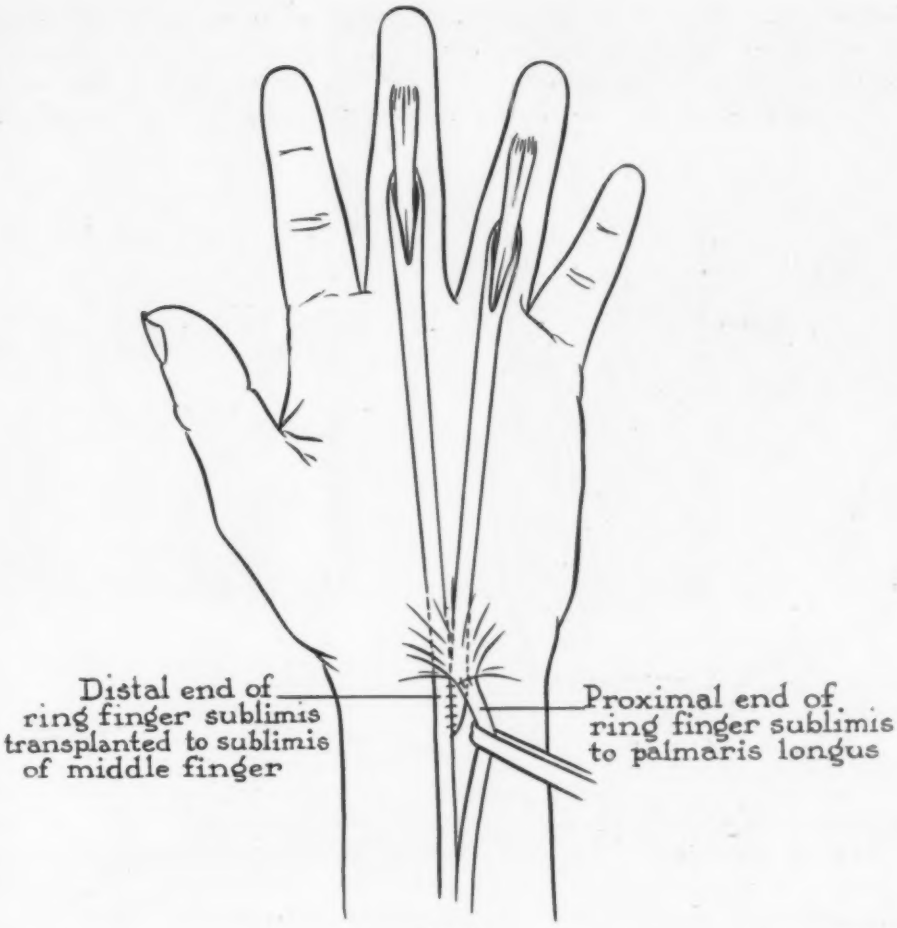

FIG. 10

For radial-nerve paralysis, all wrist flexors are transplanted posteriorly for extension of the digits; the sublimis of the ring finger is then transplanted to the wrist for stabilization of the wrist.

carried out at a later date, if the subject finds that his occupation demands a more stable wrist. To offset this objection to the transplant, the authors transplanted two sublimis tendons into the extensors, thus preserving at least one strong wrist flexor (Fig. 9-A). The sublimis muscles, however, have short tendons in the forearm, which do not lend themselves well to posterior transplantation; thus the extension which the patient obtained was somewhat limited (Figs. 9-B and 9-C). Then the usual transplantation for radial-nerve paralysis was carried out and, in addition, one or two sublimis tendons were transplanted into the wrist for flexors with, the authors feel, definite improvement in function * (Fig. 10). It must be remembered that the wrist muscles act not only to flex and to extend the wrist, but also to stabilize it. Therefore, anything which gives more stabilization on the flexor side of the wrist in these transplantations of radial nerve and tendon increases the power of the grip. Most of the individuals with tendon transplants for radial-nerve paralysis get along well without additional wrist flexors; nevertheless, when additional support is given, they are improved.

At Letterman General Hospital, tendon transplantations for radial-nerve paralysis have been carried out on forty-two patients. Of these cases, transplantations were done in thirty-one for complete radial-nerve paralysis, in seven for posterior interosseous paralysis, and in four for extensive tendon and muscle damage. The results have been

* Suggested in part by William H. Bickel, M.D., Rochester, Minnesota.

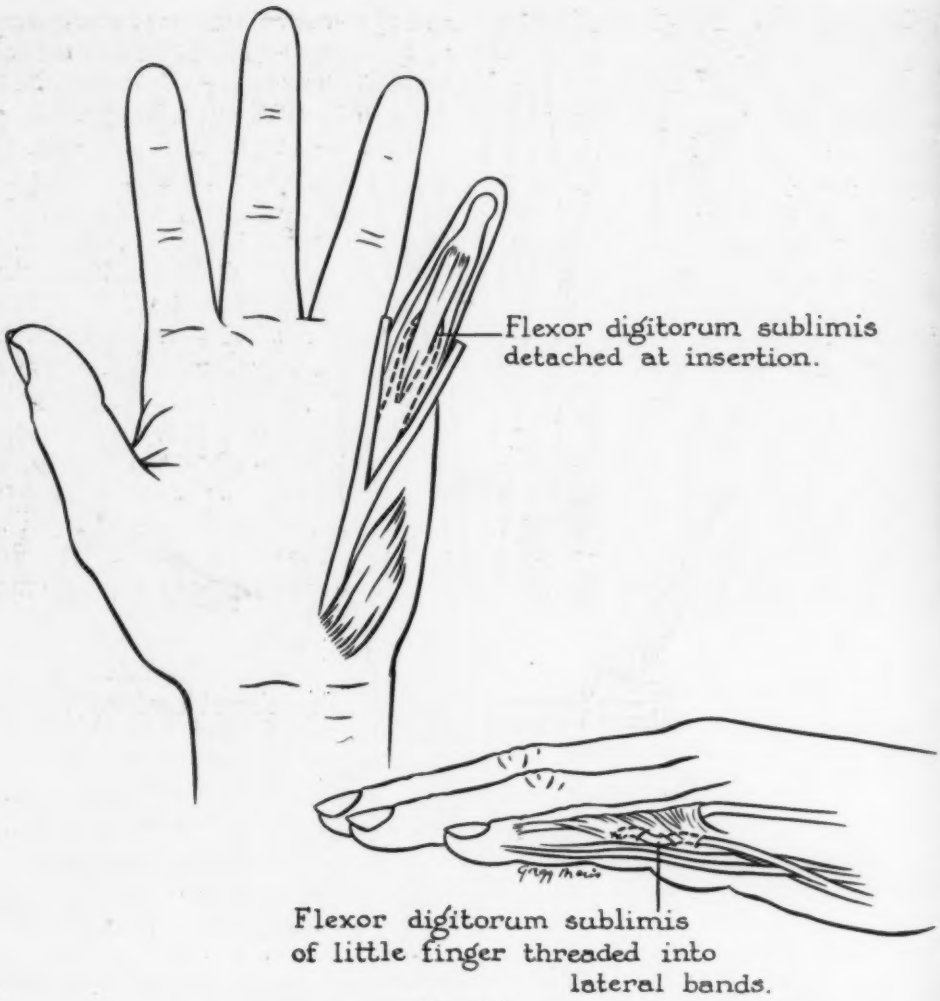

FIG. 11-A

Bunnell procedure for clawing deformity of finger, due to intrinsic-muscle imbalance. Flexor digitorum sublimis is transplanted into lateral bands and transverse fibers of extensor mechanism.

most encouraging. In one case, all three nerves were injured; however, there was a fair degree of return of function in the median and ulnar nerves. The function of the radial nerve did not return, so a tendon transplantation was done to restore extensor function. Since the transplanted wrist flexors had not regained their full power, the results were only fair. The authors strongly advocate wrist fusion in these cases. Even though one feels that adequate power of contraction has returned to the muscle, it may not function well in a transplanted position.

ULNAR-NERVE PARALYSIS

The ulnar nerve supplies most of the intrinsic muscles of the hand, and the return of function in the hand after nerve suture is not always satisfactory. Frequently there may be sensory return and return of activity to the long flexors, but no motor activity in the small muscles. The amount of clawing of the ring finger and the little finger varies considerably, even among patients with complete nerve lesions at the same level. In some cases, the clawing is mild; and the patient does not desire to have, nor does he need, surgical correction. In others, the clawing is so severe that the patients are unable to extend the last two phalanges far enough for satisfactory function. Transplanting the sublimis

FIG. 11-B

FIG. 11-C

FIG. 11-D

Fig. 11-B: Shows clawing of finger following injury to palm and loss of intrinsic activity.
Figs. 11-C and 11-D: Show flexion and extension achieved after operative procedure described in Fig. 11-A. Excellent results have been obtained by transplanting flexor sublimis to tranverse fibers and lateral bands.

of the involved finger into the transverse fibers and lateral bands of the extensor mechanism, as devised by Bunnell [5], overcomes the clawing and still permits good flexion. Lesions of the palm will also produce clawing. They are treated in a similar manner. One slip of the sublimis can then be transplanted onto each side of the finger (Figs. 11-A, 11-B, 11-C, and 11-D). If the ulnar-nerve lesion is sufficiently proximal to paralyze the profundus tendons of the ring finger and the little finger, the sublimis of the long finger must be used, one slip going to the ring finger and one slip to the little finger. The results in these cases do not compare favorably with the results obtained when the sublimis of the involved finger is transplanted to the extensor mechanism of the same finger (Figs. 12-A, 12-B, and 12-C).

In one case of ulnar-nerve paralysis, in which there was excessive clawing and the sublimis tendon was not satisfactory for transplantation into the extensor mechanism, the lateral bands of the extensor mechanism were sutured together over the dorsum of the proximal interphalangeal joints. Thus the extensor tendon acted to extend the interphalangeal joints. Definite improvement was noted, but only one case was treated in this manner. Further work will have to be done before this procedure can be evaluated adequately.

If the profundus action of the ring finger and the little finger does not return satisfactorily, these tendons can be sutured to the adjacent profundus tendons [6, 14]. However, this is seldom necessary in the presence of good sublimis activity. In addition, since length can be gained by anterior transplantation, the ulnar nerve can usually be sutured; individuals upon whom this has been performed usually regain profundus activity, although it may be quite weak.

The author feels that, if there is good activity of the long flexor and good opposition of the thumb, restoration of adduction power of the thumb is not highly important. For that reason, the authors have never resorted to tendinous reconstruction for this function.

Restoration of abduction of the index finger to aid in pinch is achieved by use of the

extensor indicis proprius, as shown in Figure 1-A. A similar procedure is used to restore abduction of the little finger by utilization of the extensor digiti quinti [5].

The area of absolute anaesthesia in ulnar-nerve paralysis is limited to the little finger. Whether or not the anaesthetic little finger should be excised depends largely upon the occupation of the patient. If he works with machinery, or if he is subject to temperatures which might produce burns, the finger should be amputated. The decision should be made by the patient.

Transplantation of the sublimis to overcome clawing of the fingers, due to intrinsic-muscle loss, has been carried out in thirteen cases at Letterman General Hospital. Improvement in the clawing occurs invariably, and usually the improvement is quite pronounced. Flexion may be limited for a short while, but it soon returns. One must remember that only a small proportion of individuals with intrinsic-muscle damage have enough clawing to warrant surgery.

MEDIAN-NERVE PARALYSIS

In lesions of the median nerve in the distal part of the forearm, the chief disability, in addition to the sensory loss, is the loss of ability to oppose the thumb. Numerous methods for restoration of opposition of the thumb have been described. In 1921, Ney suggested transplanting the proximal end of the tendon of the extensor pollicis brevis subcutaneously across the thenar eminence and suturing it to the palmaris longus, but pulling deep to the transverse carpal ligament. Bunnell [4] subsequently transplanted the tendon volar to the transverse carpal ligament, and pulled from the direction of the pisiform. In addition, to utilize the motion at the metacarpophalangeal joint, Bunnell suggested that the tendon have its effective pull from the base of the proximal phalanx rather than from the metacarpal head. The sublimis tendon has also been used to restore opposition [12]. One advantage of this procedure is that there is no tendon suture along the gliding portion of the tendon. The chief difficulty in restoring the function of opposition to hands which have been injured in war is in mobilizing the metacarpal of the thumb. Many of the patients have

FIG. 12-A

Shows clawing due to ulnar-nerve paralysis, before operation.

FIG. 12-B

FIG. 12-C

Show flexion and extension possible after sublimis tendons of the little finger and the ring finger have been transplanted to their respective extensor mechanisms, as shown in Fig. 11-A.

considerable scarring and fibrosis about the base of the thumb metacarpal. This is due to direct trauma, to prolonged immobilization, or to Volkmann's ischaemia. Excision of the scar about the base of the metacarpal, followed by extensive active and passive motion, produced improvement in some, while osteotomy of the metacarpal has been necessary in other cases.

Observation of a relatively large number of median-nerve injuries revealed that, in addition to lack of return of intrinsic-muscle function, there frequently was little or no return of function in the flexor pollicis longus. This was true even after a prolonged period had elapsed since the nerve repair. Flexor pollicis longus action is restored, as described previously (Figs. 4-A, 5-B, and 6-A). Activity of the long flexors in cases of high irreparable lesions of the median nerve is restored by utilizing the remaining active and available long muscles of the forearm, as was described originally by Stiles and Forrester-Brown.

PARALYSIS OF THE MEDIAN AND ULNAR NERVES

Fig. 13: Modified Royle procedure for paralysis of opponens pollicis. Flexor digitorum sublimis of ring finger is looped around flexor carpi ulnaris, transplanted subcutaneously across thenar eminence, and sutured into thumb metacarpal and proximal phalanx. If this procedure is used, the slip to the phalanx must be sufficiently taut so that the metacarpophalangeal motion will be utilized, as emphasized by Bunnell.

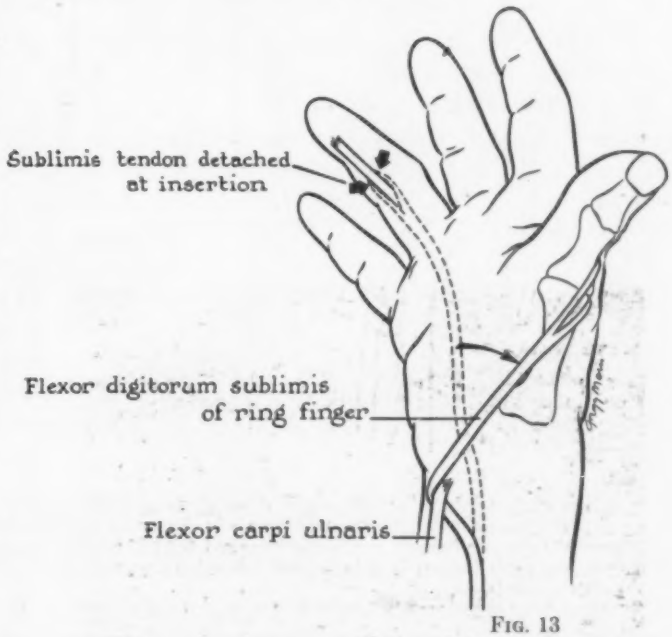

FIG. 13

Irreparable lesions of the median and ulnar nerves above the forearm produce a severely crippled hand. In many cases, suture of these nerves is satisfactory, and function returns to the long flexors. In the authors' experience, however, the intrinsic muscles of the hand seldom regain satisfactory function, so that the methods described by Bunnell must be employed for restoration of normal function. In the cases of irreparable injury, one utilizes the muscles supplied by the radial nerve [6, 14]. In order that all the wrist extensors may be used, the wrist should be fused. If it is fused in too much dorsiflexion, the transplanted tendons do not seem to flex the digits well. The authors arthrodese the wrist in the manner described by Abbott, Saunders, and Bost. This procedure retains motion at the carpometacarpal joint, which the patients find very useful because it permits the palm to be mobile.

After the wrist has been fused, all three of the dorsiflexors of the wrist and the brachioradialis can be used for flexion of the digits and opposition of the thumb. The authors first transplanted the extensor carpi radialis longus into the flexor pollicis longus and the flexor digitorum profundus of the index finger, and the extensor carpi radialis brevis into the flexor digitorum profundus of the long finger, ring finger, and little finger. The most difficult task was to get the thumb to move in a proper functional relationship to the fingers. The interphalangeal joint of the thumb had a tendency toward excessive flexion, in spite of adjustment of tension of the transplant and re-education of the patient. To overcome this objection, the authors have transplanted the brachioradialis to the flexor pollicis longus, and the extensor carpi radialis longus and extensor carpi radialis brevis into the

finger flexors (Figs. 15-A, 15-B, and 15-C). (The range of excursion of the brachioradialis has been found to be 1.5 centimeters.)

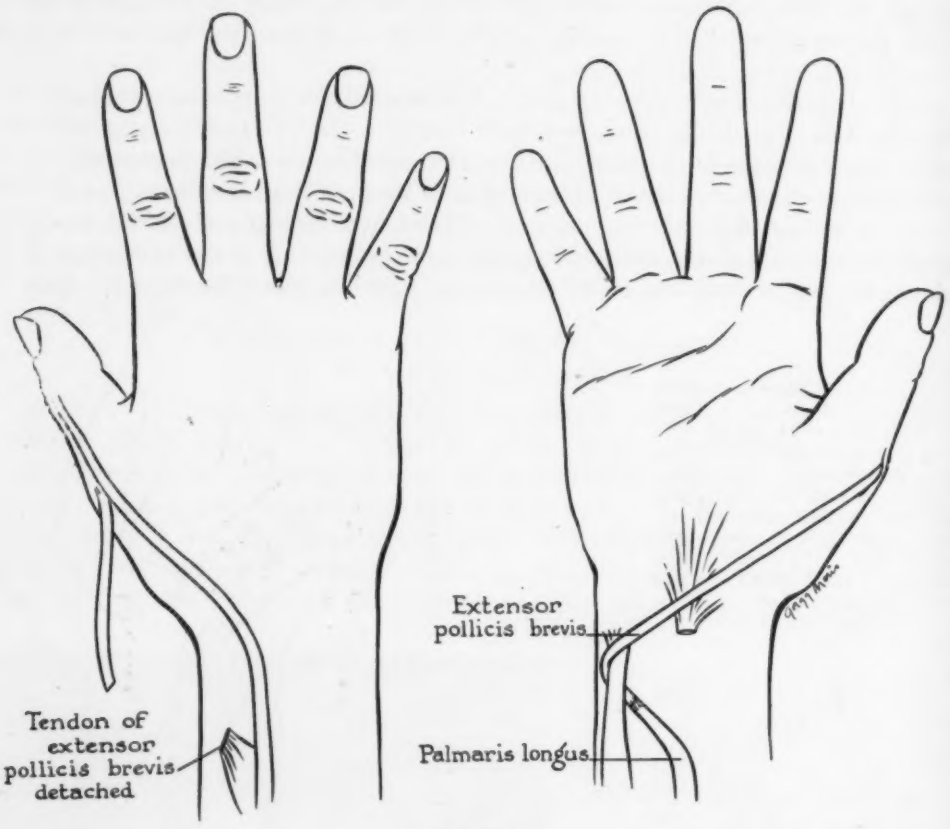

FIG. 14-A

Bunnell procedure for correction of paralysis of opponens pollicis is carried out as follows:
1. Tendon of extensor pollicis brevis is detached proximally, transplanted subcutaneously across thenar eminence, and looped around tendon of flexor carpi ulnaris.
2. Palmaris longus is detached at insertion and sutured to transplanted tendon of extensor pollicis brevis.

FIG. 14-B

FIG. 14-C FIG. 14-D

Fig. 14-B: Shows clawing of long finger, ring finger, and little finger, before operation.
Figs. 14-C and 14-D: Postoperative photographs show extension and opposition achieved by procedure described in Fig. 14-A.

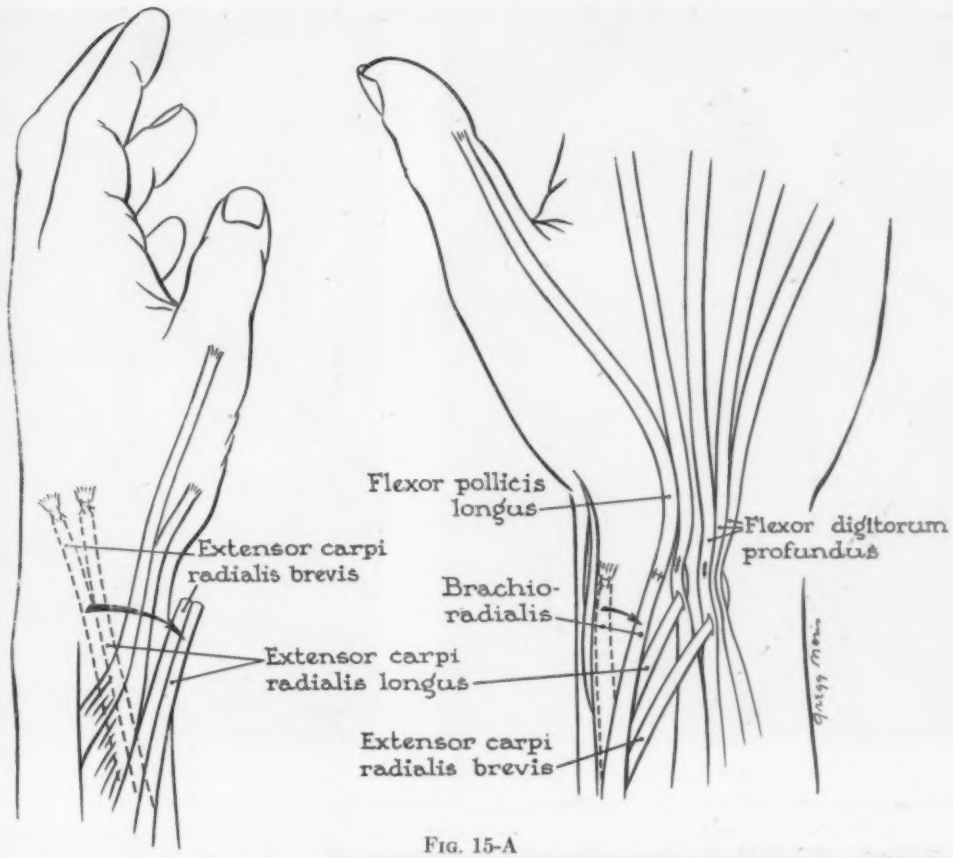

FIG. 15-A

Modified Bunnell procedure for correction of paralysis of median and ulnar nerves includes the following steps:

1. Arthrodesis of wrist.
2. Extensor carpi radialis longus is transplanted into flexor digitorum profundus of index finger.
3. Extensor carpi radialis brevis is transplanted into flexor digitorum profundus of long finger, ring finger, and little finger.
4. Brachioradialis is transplanted into flexor pollicis longus.

To restore opposition of the thumb, the extensor pollicis brevis tendon is detached proximally, transplanted subcutaneously across the thenar eminence, as shown in Figure 14-A, and sutured to the extensor carpi ulnaris, which is transplanted around the ulnar side of the forearm[6].

The range of the wrist extensors is approximately one and one-quarter inches; the long flexors of the fingers glide through a range of two and three-quarters inches, according to Bunnell. With this in mind, the proper tension of the transplants should be determined. The fused wrist provides an advantage, since all the motion will be in the finger joints and none will be taken up by a mobile wrist. If the tension is too great, there will be excessive clawing, and the thumb and fingers will not come together in a functional position. On the other hand, excess length will allow for complete extension, but will not permit enough flexion for a satisfactory grasp. The authors feel that the tension should be such that the proximal two joints would be permitted to extend to about 140 to 150 degrees at the time the transplantation is done, and the distal joint would be permitted to extend to about 160 degrees. The tension on the transplant for thumb opposition should be too much rather than too little.

In two of the authors' cases of paralysis of the median and ulnar nerves, extensive fibrosis of the flexor muscles in the forearm and of the intrinsic muscles of the hand was also present. In spite of extensive excision of scar tissue around the base of the thumb, the

FIG. 15-B

FIG. 15-C

Show extension and flexion possible after operation by procedure described in Fig. 15-A.

FIG. 16

Fig. 16: Bone block of thumb metacarpal to maintain position of opposition. This procedure should be used when the thumb metacarpal is not sufficiently mobile, when suitable muscle and tendon are not available to restore active opposition, or when these conditions coexist.

metacarpal did not become sufficiently mobile to justify a tendon transplantation; so a bone block was done (Fig. 16). The bone block seems to be indicated in some cases of Volkmann's ischaemia with extensive fibrosis of the muscles, especially if the forearm muscles are also badly damaged, thus prohibiting a successful transplantation. Considerably more difficulty is involved in obtaining satisfactory function of the hand when there is ischaemic necrosis and fibrosis of the muscles, in addition to paralysis of the median and ulnar nerves, than when the nerves are damaged and extensive fibrosis of the muscles does not exist. Clawing of the fingers is an inevitable sequela in these individuals, due to the absence of intrinsic-muscle function. If clawing becomes extensive, the interphalangeal joints which are responsible for most of the deformity can be fused in partial flexion. We have never carried out this procedure in this group, but it is a

likely possibility. This procedure should not be entered into hurriedly; if, at a later date, the patient finds that the clawing interferes with his work, the joint can then be fused.

Slitting the pulleys at the base of the fingers to permit some bowstringing of the tendons and a more effective pull [6] has been done in one case. It has not resulted in any functional advantage, as far as the authors have been able to determine.

INJURIES TO THE BRACHIAL PLEXUS

Injuries to the brachial plexus have been relatively frequent, because of the exposure of the shoulder on the battlefield. Neurosurgeons have been able to repair many of these, and the return of function has been surprising in some instances. In others, there is a spotty return of function; and reconstruction depends upon the muscles available and their use in one of the ways described previously. Stiles and Forrester-Brown state that the varieties of transplants used for incomplete injuries are almost as numerous as the tendons. Sometimes all the nerves show evidence of return of function, but the end result is excessive weakness of all the muscles. In these instances, arthrodesis of the wrist materially increases function, since all the motion is then transmitted to the finger joints. In addition, if the wrist flexors or extensors, or both, are functioning, they are then available for transplants.

CONCLUSIONS

Most of the reconstructive procedures of the hand which are employed in permanent nerve paralysis, discussed in this paper, have been employed previously, but some of them are new. For a transplantation to be successful, one must first mobilize the joint, eliminate scar tissue, and then transplant a normally functioning tendon and muscle through normal tissue. Flexors can be transplanted to extensors and extensors to flexors, with excellent results. In most instances, the muscle transplanted should be the one which is most readily available and which has a range of motion as nearly as possible like that of the muscle and tendon it is intended to replace.

NOTE: All the hand drawings were made by Gregg Moris, Medical Artist at the Letterman General Hospital. The photographs were taken by the Photographic Laboratory, Letterman General Hospital.

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DISCUSSION

DR. STERLING BUNNELL, SAN FRANCISCO, CALIFORNIA: Repair of flexor tendons in the fingers is most difficult, and many surgeons are skeptical about its success. That good results can be obtained by adherence to these principles, which for many years I have been advocating, was demonstrated not by one, but by many of the officers assigned to that work in the Army. I have had the pleasure of seeing many of Dr. Graham's 141 cases of flexor repair; and I and many others can assure you that his results were excellent.

This short paper by Dr. Graham covered many of these principles which, if not observed, mean failure. If one operates with trauma, repairs tendons when joints are stiff, places junctures at wrong sites where they will adhere, disregards the gliding mechanism, or ignores the essential principles that should be adhered to, the tendon will become bound in its channel.

It has been found that a graft of a gliding assembly—that is, tendon plus paratenon, such as the palmaris longus—will usually give a much better result than will a smooth tendon graft, such as the sublimis with its epitenon.

There is a zone which I call "no man's land", where tendon junctures will adhere. It is between the distal crease in the palm and the middle crease in the fingers. When tendons are severed in this zone, the sublimis tendon must be removed.

By resorting to a tendon graft, we may place our tendon junctures where they will do no harm. The insertion in the last phalanx does not have to glide, and a juncture in the base of the palm or above the carpal ligament can glide. In the former instance, the lumbricalis is wrapped about the juncture, where it is naturally attached to the profundus tendon. Should a graft adhere, it often may be liberated by grafting paratenon or the slippery side of deep fascia beneath it. We should strive for a minimum of moving parts and a maximum of gliding material.

Dr. Luckey's paper tells of the types of tendon transfers commonly done in the various Army hospitals in World War II, and gives some valuable practical points gained from actual experience in the work.

All patients with lesions of arm nerves should, before dismissal, have orthopaedic consideration for possible tendon transfers.

Cases differ so much, in their bizarre combinations of paralyses, that one must leave the beaten paths of set methods and be guided by main principles. After the number of actions needed and the number of muscles available have been estimated, the available muscles should be divided up so as to supply the needs.

If active tendons are insufficient in number to move the various joints, as they are whenever any two of the three main nerves are cut, we should arthrodese the wrist. This makes some of the five wrist tendons available for use on the digits. If sufficient tendons are still not available, we should arthrodese enough joints so that the few tendons which we have will activate the remaining joints. We may thus solidify the wrist, the forearm in slight pronation, the base of the thumb by a bone block, or the middle joints of the fingers.

When there are insufficient active tendons, another procedure is to use the principle of tenodesis, which will furnish automatic motions. For instance, in paraplegia between the sixth and seventh cervical segments, the only motion of the hand is strong dorsiflexion of the wrist. Tenodesis of all digit flexors to the radius and of a tendon to the ulna which will draw the thumb into opposition will, when the wrist is extended, flex all digits and oppose the thumb.

The distance of excursion of transferred tendons is important. In the thumb, since the abductor has half the excursion of the long extensor, a single tendon joined to both cannot produce full motion. Wrist tendons which move one and one-quarter inches cannot impart full motion to digit extensors which normally move from two to three inches. Therefore, correction for radial palsy very rarely gives complete movement.

For paralysis of the intrinsic muscles of the hand, many different tendons can be used to restore muscle balance. Thus in paralytic claw-hand, the thumb is made to oppose and adduct, the index finger to abduct for pinch, and the metacarpal arch to curve. The finger clawing goes with restoration of muscle balance. These transfers have, as stated in this paper, been proved to be successful and practical.

Both of these papers are valuable and show what can be accomplished.

DR. L. D. HOWARD, JR., SAN FRANCISCO, CALIFORNIA: As far as the work of the Hand Centers during World War II is concerned, I think most of you are familiar with the general set-up of the program. Sometime in the latter part of 1944, Dr. Bunnell was asked by the War Department to be Chief Consultant in establishing these Centers throughout the country. Nine Centers were established. Dr. Bunnell's ability from a teaching and organizational standpoint can only be measured by the brilliant results obtained. There is an intense interest in this work by members of the orthopaedic profession, and rightly so. I believe it is important work, and I think all of you are taking active interest in getting better function of hands.

DR. GEORGE S. PHALEN, CLEVELAND, OHIO: Dr. Graham, Dr. Luckey, and Dr. McPherson are to be complimented on their presentations, as well as on the excellent manner in which they have restored these badly crippled hands to a state of usefulness.

We who were fortunate enough to have been stationed at Army General Hospitals which were designated as "Hand Centers" had the exceptional opportunity to see and treat a large number of hand cases. In a Hand

Center which was also a Neurosurgical Center, there were numerous cases of irreparable nerve injury; and almost all of these cases required some type of tendon transfer to restore efficiency to the paralyzed hands.

The tendon transfer for radial-nerve paralysis is the one which is probably used most widely; and the end results from this tendon transfer are almost universally good. I agree with Dr. Luckey that it is most important that the transferred flexor tendons in these cases of radial-nerve palsy be placed under considerable tension. The effective range of motion in the wrist and hand should be largely above the horizontal plane. With the wrist extended about 30 degrees, the patient should be able to extend the fingers to the plane of the palm and to flex the fingers into a firm fist. When the transferred tendons are placed under such tension, the patient is no longer able to make a fist with the wrist flexed; but this, of course, is not a purposeful or useful movement and causes no disability.

We preferred to transfer the flexor carpi radialis into the long abductor and the two extensors of the thumb, leaving the extensor tendon of the index finger to be included with the other finger extensors in the transfer of the flexor carpi ulnaris. In all cases of irreparable damage to only the deep branch of the radial nerve, we did what we called a "triple transfer at the wrist": The flexor carpi ulnaris was used to motivate the finger extensors, the extensor carpi radialis brevis was used to activate the long thumb extensor, and the palmaris longus was transferred into the long abductor and short extensor of the thumb. In this manner, the flexor carpi radialis was left undisturbed and served to stabilize the wrist.

In the restoration of function in these tendon transfers, the patient's condition must be checked frequently to be sure that a tenodesis action is not being substituted for a true contraction of the transferred muscle. For example, a patient with a transfer of the flexor carpi ulnaris into the extensor digitorum communis will soon find that permitting his wrist to flex will automatically cause extension of his fingers, due to the checkrein effect of the transfer of the flexor carpi ulnaris. He will find it easier to extend his fingers by this "checkrein" effect than by actually contracting the transferred tendon. Occasionally, galvanic stimulation of the transferred muscles will give the patient the "feel" of the muscle now performing an entirely new function, and this may better enable him to re-educate himself.

I believe one cannot stress too strongly the importance of joint mobilization prior to tendon transfer or tendon grafting. Certainly if the fingers cannot be flexed and extended passively, no tendon graft or transfer will ever restore these functions. Fortunately, in peripheral-nerve injuries there is frequently little or no damage to the hand itself; but the hand may have become stiffened from circulatory impairment, from trophic changes, or from prolonged splinting of a fracture of the forearm or upper arm. These hands *must* be mobilized as completely as possible prior to any tendon transfer. This sometimes implies that operative steps must be taken prior to the transfer, such as capsulectomy of the metacarpophalangeal joints, adductor stripping of the thumb, tenolysis,—especially of the extensor tendons, or application of a skin graft to supply the necessary mobility of the invclved joints. The performance of such operations at the same time as the tendon transfer is not advisable.

In incomplete median-nerve paralysis, there may be return of some power in the finger flexors, but this power may not be sufficient to give the patient an adequate grip. Reinforcement of the finger flexors may be carried out by transfer of either a wrist flexor or a wrist extensor muscle into the finger flexors. Extension of the wrist and flexion of the fingers is more of an associated movement than is flexion of the wrist and flexion of the fingers. In the cases in which fusion of the wrist was not advisable, we found that better strength in flexion of the fingers was obtained by transferring the extensor carpi radialis longus or brevis into the finger flexors than by using the flexor carpi radialis.

I believe it is important, before performing a flexor-tendon graft, to explain to the patient just what may be expected from this operation. The patient usually anticipates that the finger will function again in a perfectly normal manner, although actually—even with the very best tendon graft—he will never be able to strongly clench the finger down into the palm. If he is able even to touch the tip of the finger to his palm, the result is considered excellent.

If arthrodesis of the wrist is included in the reconstruction program outlined for a particular hand case, I believe this operation should be postponed until after the flexor-tendon graft has been done. Flexion of the wrist at the time of the flexor graft aids considerably in determining the degree of tension on the graft, and prevents flexion contracture of the finger, which may develop with too much tension.

Dr. Walter C. Graham, Santa Barbara, California (closing): I want to thank the discussors. Dr. Phalen brought out a very important point which should be stressed, and that is the complete mobilization of the joints before tendon-grafting. It is important that no tendon graft be done to a finger which is without sensation. The effort of the patient following operation is the most important single point in restoring function.

Dr. C. A. Luckey, Oakland, California (closing): I want to thank Dr. Bunnell, Dr. Howard, and Dr. Phalen for their remarks. Dr. Phalen has emphasized his work of transplanting the extensors into flexors, and we thoroughly agree with him. In the presence of a fused wrist, one can transplant wrist flexors into digit flexors with reasonably good results. However, if the wrist is not fixed and if the wrist flexor is used to activate a digit flexor, there will be difficulty in getting as much motion as one would like to have.

RECURRENT POSTERIOR DISLOCATION OF THE SHOULDER

BY J. C. R. HINDENACH, M.D., F.R.C.S., LONDON, ENGLAND

Posterior dislocation of the shoulder is a rare lesion. Thomas described seven cases, and stated that in 6,000 roentgenograms of the shoulder, four cases of posterior dislocation had been found. Fèvre and Mialaret found that out of every 100 recurrent shoulder dislocations, three were posterior, and that most of the recurrent cases were of congenital origin. The proportion of primary to recurrent lesions could not be ascertained.

The classification of the disability is confused. Möllerud quoted Blumensaat's classification of the patellar luxations, applying it to the shoulder:

1. Fresh luxations, arising in direct succession to an adequate trauma;
2. Recurrent luxations which occur more or less "spontaneously" now and then, at longer or shorter intervals, and are more or less sequelae of the primary luxation;
3. Permanent luxations:
   (a) Habitual (when the patella is luxated at every flexion of the knee joint), and
   (b) Constant (when the patella never occupies its normal place during any part of the movement of the knee).

The diagnosis of primary posterior dislocation of the shoulder is often missed, as the disability may not be severe, and the range of motion may be only slightly limited. Palpation of the head of the humerus below the spine of the scapula and the presence of an abnormal hollow below the acromion are the salient features. Anteroposterior roentgenograms are very misleading, because they may show a normal outline of the shoulder joint. Lateral views through the chest, or supero-inferior views through the axilla, display the abnormal position of the head of the humerus.

The recurrent and permanent types tend to become confused, and they overlap in the region of the shoulder. Argument has arisen over the distinction between the recurrent and the permanent habitual classes. A shoulder may be dislocated posteriorly by trauma, and although adequate reduction may be performed, the dislocation may recur every few months following specific strain. This is a true recurrent type. However, following an original dislocation, the disability may recur every time the arm is abducted, or flexed and elevated. Such a condition, although recurrent, is also habitual. True habitual posterior dislocation of the shoulder, however, often occurs in young adults without history of primary injury, and it is commonly bilateral.

Short summaries of some of the cases reported may clarify the classification. Rowe and Yee described a posterior approach to the shoulder, and gave case reports of two soldiers, each with a similar lesion. Both men were twenty-two years old, of good muscle development; they had sustained original injuries to their shoulders, which resulted in posterior dislocations. Following reduction, there were numerous recurrences, until the disability recurred every time the affected arm was flexed and elevated. When the muscle was relaxed, or when traction was applied to the arm, the shoulder returned to normal. A Nicola operation which was performed upon one patient had produced no improvement. Both patients were operated upon through a posterior approach, the labrum was sutured to the bone (Bankart's technique), and full function was restored.

Möllerud reported a girl of eighteen years who had noticed a slip in the left shoulder for several years, and in the right for about two. When the left arm was stretched forward and upward and rotated medially, the head of the humerus slipped backward, and could be felt under the spine of the scapula. When the arm was brought back to the normal position, the bone returned to its place with a jerk. The shoulder luxation could not be pro-

duced, when the arm was rotated externally. The right shoulder had a similar tendency, which was not so pronounced. Roentgenograms were normal.

Sjövall's case was a man of twenty-two years who had had discomfort in his shoulder for two years, and could produce backward luxation by stretching his arm forward and upward in internal rotation.

Asplund described a boy of eighteen years of age in whom backward luxation resulted when his right arm was abducted to 50 degrees and then stretched forward during simultaneous internal rotation. This applied to both shoulders. It was suggested that during internal rotation the external rotator muscles failed to act as a posterior brace to the head of the humerus. In the roentgenograms a flat posterior part of the glenoid was visible, and arthrography showed a large posterior recess. At operation the labrium glenoidale was absent on one side. A posterior bone graft, projecting from four to five millimeters laterally, was inserted with good results.

Asplund stated that his case was that of a "*schnappender Schulter*", or "snapping shoulder", and that it was voluntary and habitual. Voluntary is described as being related to an act, habitual to a frailty. Möllerud, however, considers that Asplund's case was truly recurrent and not habitual, and his point of view is probable because at operation the labrium glenoidale was absent, thus suggesting a primary traumatic factor.

Congenital posterior dislocation of the shoulder has been described by several French writers. The primary lesion is commonly a small glenoid fossa. Ombrédanne states that, unlike congenital dislocation of the hip, the condition in the shoulder cannot be cured by reduction and adequate retention in the normal position. Posterior slipping always occurs. Various bone-graft operations have been used in its repair.

TREATMENT

Usually the true recurrent type of posterior dislocation which is due to trauma has a detached labrium glenoidale. Bankart's method of repair gives good results. The approach to the joint is well described by Rowe and Yee, who dealt with two cases, and by Harmon, who modified the technique slightly. An incision is made from the middle of the scapular spine along and just inferior to it as far as the tip of the acromion. The origin of the deltoid is dissected subperiosteally from the spine, and the muscle flap is freed from the deeper structures, and reflected laterally and inferiorly. Care is taken not to exert gross traction or to use deep retractors, for the circumflex nerve may be damaged. The bellies of the infraspinatus and the teres minor are thus exposed, and then separated, and the latter is retracted. Therefore, the contents of the quadrilateral space are protected. The attachment of the infraspinatus is divided one-half inch from its insertion into the greater tuberosity of the humerus, and is reflected medially from the underlying capsule and scapula. The region of the great scapular notch with the terminal branches of the suprascapular nerve must be avoided. An excellent view of the entire posterior aspect of the shoulder capsule is obtained. When trauma has been the cause of the lesion, the capsule with the labrium glenoidale will be found detached from the posterior margin of the glenoid fossa. A method similar to that used by Bankart for anterior recurrent dislocations may be used to repair the lesion. The posterior surface of the glenoid neck and rim is "rawed", and four or six drill holes are bored through the rim. The drilling is simpler here than in the anterior part of the joint. The approach is direct, and an angled drill is unnecessary. The capsule is reattached to the scapular neck by mattress sutures through the drill holes. The cut tendon of the infraspinatus is sutured, the deltoid is reattached to the spine of the scapula, and the skin is closed. The flexed arm is bandaged to the side for six weeks, with the wrist and fingers left free. Active movements are then encouraged.

In the voluntary or habitual type of recurrent dislocation, no detachment of the labrium glenoidale may be found. Often a general bulging of the capsule is observed. The capsule should be incised vertically one-third of an inch from the glenoid, so that the joint

can be inspected. If no further abnormality is seen, some posterior support to the joint must be provided. Kaplan has treated two cases by using a "reversed Clairmont operation", bringing a portion of the anterior deltoid through the quadrilateral space to be attached posteriorly. He reports good results.

A more stable support can be obtained by using a posterior bone graft. Rocher has used a tibial graft, inserted extracapsularly under the infraspinatus and projecting four millimeters laterally beyond the glenoid. Fèvre and Mialaret have obtained their grafts from the eighth rib posteriorly, splitting it longitudinally into two and inserting both grafts deep to the infraspinatus. They completed the operation by fixing the arm in plaster in a position of abduction and external rotation. This position puts little strain upon the posterior aspect of the joint.

Ilfeld and Holder treated anterior recurrent shoulder dislocation with a graft from the ilium, employing one-half of the thickness of the iliac crest and the outer cortex of the ilium. The graft, two by one and one-half inches, is naturally curved to fit the glenoid neck. It can be fixed against the "rawed" bone with a Vitallium screw, and lies extracapsularly, being allowed to project four millimeters laterally. The arm is fixed to the side for six weeks.

The congenital type of recurrence is usually due to an abnormal glenoid fossa, and a posterior bony buttress offers the best chance of cure. Tibial and split-rib grafts have been used with success. Ombrédanne employed an ingenious technique in a baby of twenty months. He freed the spine of the scapula from muscles, hinged it close to the great scapular notch, and swung this osteoplastic flap deep to the infraspinatus so that it lay posterior to the joint capsule. He suggested, however, that this method, although suitable in the young whose bones are still malleable, would probably not be applicable to an adult.

The old unreduced dislocation (the constant, permanent type) forms a good bony buttress for itself on the dorsum of the scapula. Limitation of shoulder range is not great, and treatment is unnecessary.

CASE REPORT

G.B., a prisoner of war, twenty-four years of age, fell on his right shoulder in April 1944, while doing physical training. He was unable to elevate his arm, and was treated with physiotherapy in a camp reception station for one month without improvement. Roentgenograms were normal. In May he was operated upon, presumably for a ruptured supraspinatus muscle. Again, there was no improvement. An anterior approach to the joint was made in September 1944, and the outer end of the clavicle was removed. Repeated posterior subluxation followed, and a Nicola operation was performed in June 1945. In spite of this, there was no improvement in function. On November 20, 1945, the patient was admitted to a British Military Hospital. Physical examination showed a well-built muscular young man. The right shoulder had three long interlacing

FIG. 1

FIG. 2

Fig. 1: Supero-inferior view through axilla, showing head of humerus in normal position.
Fig. 2: Supero-inferior view with humeral head subluxated posteriorly.

scars anteriorly and superiorly. The deltoid and all other shoulder muscles contracted strongly and actively. Passive shoulder range was limited, probably by capsular scarring from previous operations. Passive abduction was possible to 150 degrees, and elevation to 150 degrees. External and internal rotation were complete. Upon active abduction at 30 degrees, the head of the humerus was felt to slip posteriorly, and after this no further abduction was possible. A similar result followed attempted forward flexion of the shoulder. With the arm at the side, the humeral head could be made to slide posteriorly by pressure from in front. Anteroposterior roentgenograms showed a normal shoulder joint, with the outer end of the clavicle absent. Supero-inferior views through the axilla showed how the head of the humerus could be made to alter its relationship with the glenoid fossa (Figs. 1 and 2).

A diagnosis of recurrent posterior subluxation of the humerus was made, and a posterior bone-buttress operation was decided upon.

On November 26, 1945, the right shoulder joint was approached posteriorly, according to the method described by Harmon. Upon reflection of the infraspinatus, the joint capsule appeared grossly lax. The capsule was incised vertically, and the interior of the joint was inspected. The labrium glenoidale was seen intact and firmly attached to the glenoid rim. The tendon of the long head of the biceps could be identified, passing from its origin to enter the head of the humerus. This band, however, failed to prevent the head from sliding backwards when it was forced from the front. The capsule was closed by reefing with mattress sutures. An iliac graft, two inches by one and one-half, was removed from the right side of the pelvis. The graft consisted of half of the thickness of the iliac crest and the outer cortex of the ilium. With a chisel, the outer cortex of the posterior aspect of the glenoid rim and of the neck of the scapula was removed, leaving a raw bed of cancellous bone against which the iliac graft was fitted and fixed firmly by a short Vitallium screw. The graft projected laterally and extracapsularly for one-third of an inch. The infraspinatus was replaced over the graft, and its tendon was sutured. The deltoid was reattached to the spine of the scapula, and the skin was closed. The arm was bandaged to the side with the elbow flexed to 60 degrees, the wrist and fingers being left free. This position was maintained for six weeks, and then active movements were begun. Postoperative shock and discomfort were negligible.

FIG. 3

Supero-inferior view six weeks after operation, showing graft and screw.

FIG. 4-A

Fig. 4-B

Six months after operation, showing union and smoothing of the graft.

On January 15, 1946, the patient could raise his arm more than 90 degrees, and he stated that the shoulder felt stable for the first time in nearly two years. Roentgenograms showed the graft in position (Fig. 3).

A personal communication from Lt. Col. Darling, R.A.M.C., then in charge of the patient, stated that in July 1946, the patient was almost normal. He had had no further subluxations. The right arm could be raised slightly less than 180 degrees, and there was a full range of motion in all other directions. The man himself was well satisfied, and was doing his normal work as a carpenter.

Roentgenograms at that time showed that the buttress had been molded to adapt itself to the shape of the head of the humerus (Figs. 4-A and 4-B).

This case has some noteworthy features. Although related originally to an injury, the disability became immediately habitual. Despite the traumatic history, no lesion of the labrium glenoidale was found. It is the second such case reported in which a Nicola operation has been unsuccessful.

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RECONSTRUCTION OF DEFECTS OF THE TIBIA AND FEMUR WITH APPOSING MASSIVE GRAFTS FROM THE AFFECTED BONE *

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Bone defects of the tibia and femur can be bridged successfully and bone length can be maintained by the use of apposing massive bone grafts. This conclusion is based on the proved integrity of the autogenous massive bone graft [4] and on the fact that massive grafts, when placed in apposition at the site of a defect, become integral parts of each other as well as of the host bone itself. When these grafts are obtained from the affected bone, the complications associated with the removal of massive donor grafts from the opposite tibia are avoided, and normal functional use of the sound extremity is maintained. With the use of supplemental bone from the ilium, defects too great to be repaired by the use of apposing massive grafts can be reconstructed successfully by the use of a single stabilizing massive graft from the same bone, augmented by apposing iliac chips or blocks. Likewise, residual donor defects become regenerated more rapidly and completely when filled with iliac bone.

In the treatment of compound fractures of the tibia and femur in combat casualties, one of the most difficult problems encountered was non-union with loss of bone substance [6]. In order to bridge these defects in accordance with the basic principle of maintaining bone length, the technical operative procedures described here were developed. Their purpose is reconstruction of the normal architecture of tubular bone at the site of the defect by the use of apposing massive grafts. Each graft comprises one-half the circumference of the affected bone,—the so-called half-cylinder grafts described by Hey Groves. The defect is bridged with external surrounding cortex in the form of a complete cylinder, and continuity of the medullary canal is re-established.

SURGICAL PROCEDURE

Three distinct operative procedures have been developed for the tibia and femur, according to the level of the defect (Figs. 1-A, 1-B, and 1-C). The operative approach to the tibia is routine, and varies according to the presence and location of cicatricial tissue. The approach to the femur is through the standard anterolateral incision. The shaft of the affected bone is exposed subperiosteally above and below the defect, and dissection is continued to the site of non-union. All scar tissue that can possibly be removed is excised. The bone ends are freed and all poorly nourished bone is removed back to normal bone, the bone ends being squared by means of a hand saw. The defect, with longitudinal traction applied, is measured, and the pattern and length of bone grafts are determined. All grafts are removed subperiosteally, care being taken to allow periosteum and muscle attachments on the sound portions of the shaft to remain attached. The grafts are removed in the following manner: Longitudinal cuts of the superficial cortex are made with a motor saw. Crosscuts are made with drill holes and a narrow osteotome. Care is taken to complete the crosscuts before the deep cortex is cut through longitudinally; otherwise there is danger of splitting the shaft of the bone through to the adjacent joint, or of breaking through the sound portion of the bone at the level of the crosscut. The deep cortex is cut from the site of the defect toward the crosscuts by means of osteotomes and a mallet, after multiple drill holes have been placed along the plane of the desired cut in

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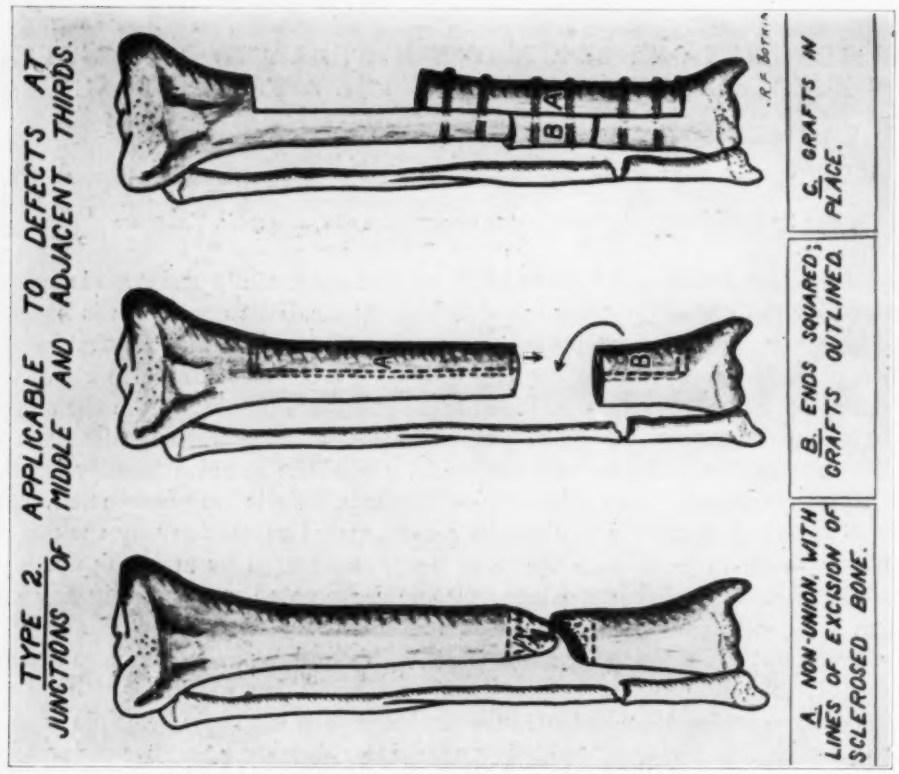
TYPE 2. APPLICABLE TO DEFECTS AT JUNCTIONS OF MIDDLE AND ADJACENT THIRDS.
A. NON-UNION, WITH LINES OF EXCISION OF SCLEROSED BONE.
B. ENDS SQUARED; GRAFTS OUTLINED.
C. GRAFTS IN PLACE.
R. F. Bonin

FIG. 1-B
Type 2 procedure.

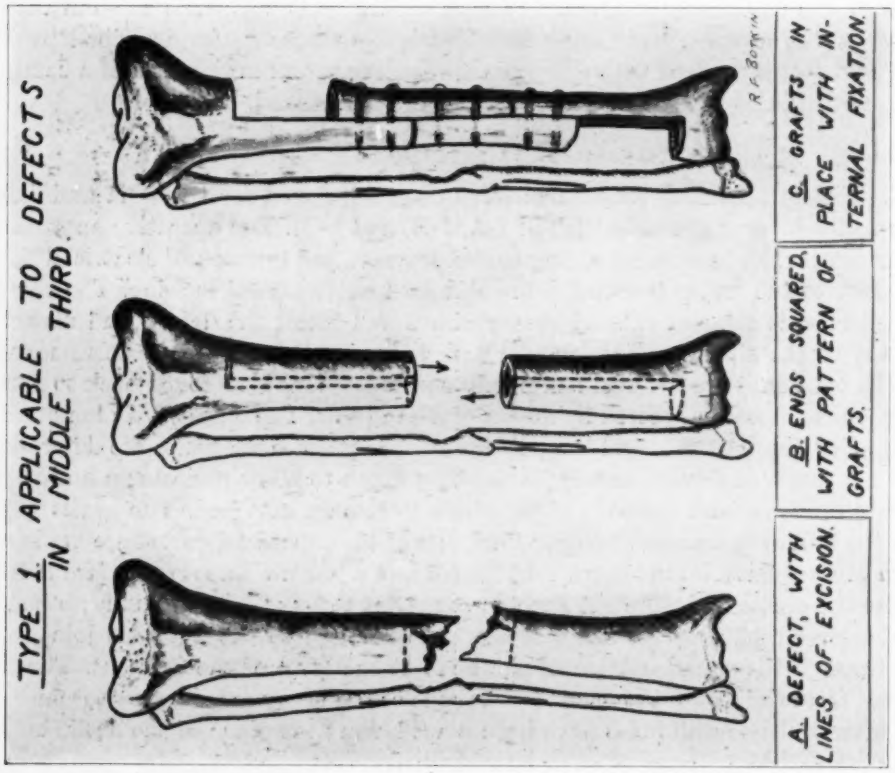
TYPE 1. APPLICABLE TO DEFECTS IN MIDDLE THIRD.
A. DEFECT, WITH LINES OF EXCISION.
B. ENDS SQUARED, WITH PATTERN OF GRAFTS.
C. GRAFTS IN PLACE WITH INTERNAL FIXATION.
R. F. Bonin

FIG. 1-A
Type 1 procedure.

Type 1 procedure.

Type 2 procedure.

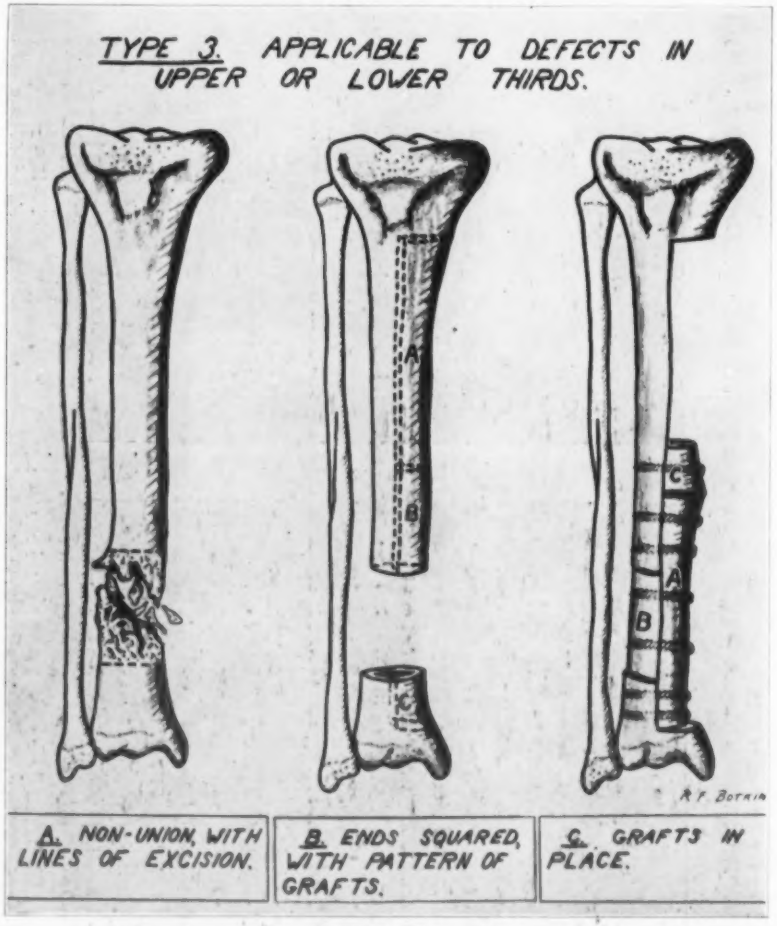

FIG. 1-C
Type 3 procedure.

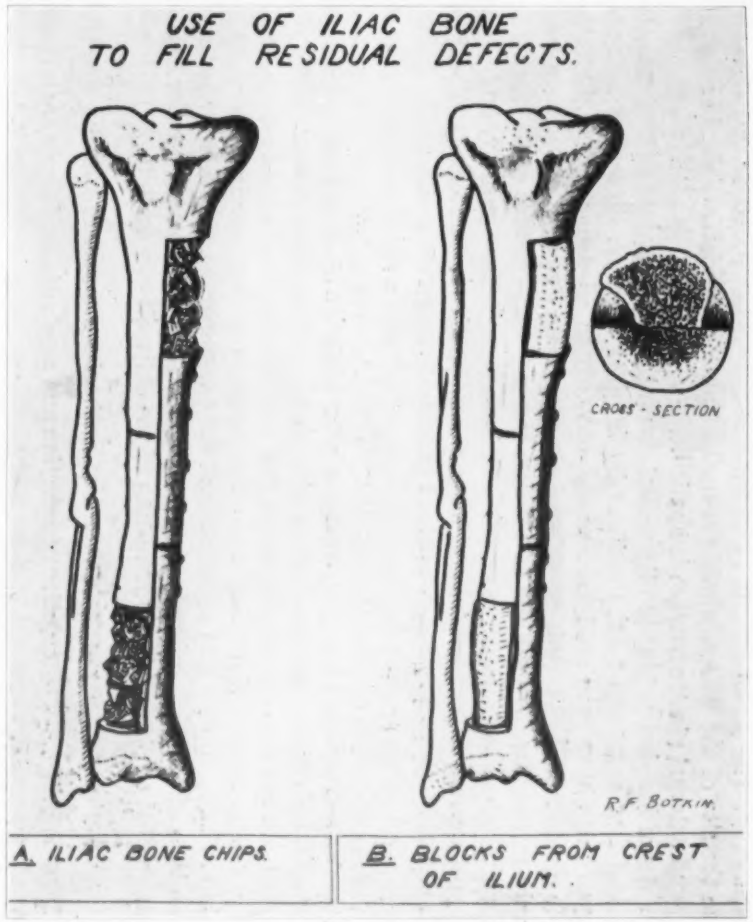

FIG. 1-D
Procedure for use of iliac bone.

the deep cortex. The grafts are then rebedded according to plan and fixed firmly with engaging screws. The periosteum is carefully closed over the proximal and distal fragments to the site of the defect, where the periosteum is non-existent. Further closure is routine, and external plaster fixation is applied.

The use of iliac-bone chips to fill residual donor defects in order to accelerate osteogenesis was first suggested to the authors by Sterling Bunnell. Since then, iliac-bone blocks and chips have been used successfully, not only to fill donor defects, but also to fill in the opposite half of very large defects, after the main fragments have been bridged and firmly immobilized by the use of a single massive half-cylinder graft from the affected bone. It has been found that this iliac bone is revitalized rapidly, and that the resulting osteogenesis is accelerated and more complete than in those cases in which the defect is allowed to become filled in unaided (Fig. 1-D).

POSTOPERATIVE CARE

After reconstruction of the tibia, a single plaster hip spica is applied and is maintained for ten weeks, followed by the application of a toe-to-groin walking plaster. The walking plaster, in turn, is removed in eight weeks, followed by the use of a toe-to-groin brace or another walking plaster, depending upon the progress of healing. In femoral cases, a double hip spica is applied and is maintained for twelve weeks. The plaster is then removed and the affected extremity is placed in traction and suspension, in order to obtain mobilization of the joints and reconditioning of the extremity as a whole.

RECONDITIONING OF THE PATIENT AND OF THE AFFECTED EXTREMITY BEFORE OPERATION

Although problems of elimination of infection and repair of skin defects are not within the scope of this paper, treatment of these complications, and the physical reconditioning of the patient[7], as well as of the involved extremity, are equally as important as the reconstruction surgery which follows. The degree of success of the reconstruction surgery is in direct ratio to the physical condition of the patient and of the extremity at the time

FIG. 2-A

FIG. 2-B

FIG. 2-A: Case 2, J. S. Preoperative bone defect.
Fig. 2-B: Anteroposterior and lateral views, five months and twenty-three days after operation by the Type 1 procedure.

such surgery is undertaken. Bone surgery should not be performed in less than three months after the compound wound has completely healed and after all obstructing cicatricial deformities have been eliminated.

Penicillin is used routinely, except in cases in which the original invading bacteria are penicillin-resistant. In these cases, sulfonamide therapy is used[5]. In cases where large soft-tissue and bone defects were treated by early saucerization and split-thickness skin-grafting [3], bone surgery should not be instituted for a period of three months after replacement of these thin grafts with full-thickness skin grafts, by means of either pedicle or tube grafts or by local skin flaps[1]. Considerable emphasis is placed upon physical reconditioning of the patient and of the involved extremity prior to reconstruction surgery. Patients with physical debility are treated with transfusions of whole blood, diets high in calories and proteins, and supervised graduated exercises. Following the healing of the compound wound, the plaster immobilization is removed and a supporting brace is applied to the affected extremity. Intensive physical and occupational therapy are utilized before operation for the purpose of mobilizing the adjacent joints, improving circulation and muscle tone, and improving the physiology of the affected bone. Motion at the site of non-union is not harmful, inasmuch as the bone ends are embedded deeply in dense fibrous tissue.

CASE REPORTS

CASE 1. A private, twenty-three years old, was admitted on July 19, 1943. He had a draining compound wound and loss of bone substance, involving the middle third of the right tibia, in addition to other injuries, as a result of a mine explosion by enemy action in Tunisia on April 21, 1943. Apposing massive bone-graft reconstruction was performed on December 15, 1943. At operation, a scar which involved the skin was excised in the line of incision; medial and lateral counterincisions were required for closure of the operative wound. A small portion of the operative incision failed to heal by first intention, which resulted in a localized low-grade infection at the site of one of the screws. *Staphylococcus aureus* was obtained on culture. Union of the bone progressed normally and weight-bearing in a supporting brace was permitted on June 1, 1944. Following excision of the metal plate and screws and of a small sequestrum, on November 22, 1944, the wound healed by first intention. The patient was discharged on April 26, 1945. The length of the defect bridged by apposing grafts was two and one-half inches. Residual shortening of the affected tibia amounted to one-half inch.

CASE 2. J. S., a captain, twenty-four years old, was admitted on February 21, 1944, twenty-four hours after a plane crash. In the accident he had sustained a compound fracture of the middle third of the left tibia with loss of bone substance, in addition to other injuries. The wound was debrided and closed primarily; and distraction pins were inserted through the upper and lower ends of the tibia and incorporated into a circular plaster in order to maintain bone length. The compound wound healed by first intention (Fig. 2-A). An apposing massive bone-graft procedure was performed on September 15, 1944. Weight-bearing was permitted on December 8, in a supporting walking plaster. A supporting brace was applied on March 10, 1945, at which time union was completely solid (Fig. 2-B). The brace was removed on August 1, 1945. The length of the defect bridged was one and one-eighth inches. Residual shortening of the affected tibia measured three-eighths of an inch.

FIG. 2-C

Anteroposterior and lateral views, fifteen and one-half months after operation.

CASE 3. A private, thirty-seven years old,

was admitted on August 27, 1944. He had a draining compound wound and loss of bone substance, involving the middle third of the left tibia, as a result of shell-fragment wounds incurred on July 12, 1944, at Saint-Lô, France. Draining had subsided and the wound had healed by January 15, 1945. Excision of the cicatrix and primary closure of the anterior aspect of the left leg were performed on March 6. An apposing massive bone-graft operation was performed on April 17. Weight-bearing in a walking plaster was begun on August 17, and the walking plaster was changed on October 15. Solid union was established. The length of the defect bridged was three and one-eighth inches. Residual shortening of the affected tibia measured one and one-half inches.

Case 4. A private, twenty-eight years of age, was admitted on November 28, 1944. He had a draining compound wound and loss of bone substance, involving the lower third of the left tibia, in addition to other injuries, as the result of a shell-fragment wound incurred on August 15, 1944, in France. Draining subsided and the wound had healed by December 11. A reconstruction of the tibia with massive apposing bone grafts was performed on April 21, 1945. Weight-bearing in a walking plaster was begun on August 17. The soldier was fitted with a toe-to-groin brace on October 27, at which time union was completely solid. The length of the defect bridged was two and three-eighths inches. No shortening of the involved tibia resulted.

Case 5. A first lieutenant, twenty-six years old, was admitted on April 8, 1945. He had a healed compound wound with loss of bone substance, involving the left tibia at the junction of the middle and lower thirds, as a result of a plane crash in France on December 11, 1944. Drainage ceased, and the wound had healed by January 11, 1945. A reconstruction with massive apposing bone grafts was performed on June 19, 1945. Ten weeks after operation, on August 28, the hip spica was removed and a toe-to-groin walking plaster was applied, at which time union was firm but not solid. The walking plaster was changed eight weeks later, on October 23, at which time union was solid. A toe-to-groin brace was applied on December 28. The length of defect bridged was one and one-eighth inches. There was no residual shortening of the involved tibia.

Case 6. T. H., a twenty-year-old private, was admitted on June 4, 1945. He had a healed compound wound of the right thigh, with non-union and loss of bone substance, involving the right femur at the junction of the middle and lower thirds, as the result of a gunshot wound by enemy action in Aachen, Germany, on November 17, 1944. The wound had healed by December 1944 (Fig. 3-A). A reconstruction with apposing massive bone grafts was performed on August 1, 1945. On November 9, a double hip spica was removed, and the extremity was placed in balanced traction and suspension; at that time union was clinically solid. An ischial weight-bearing brace was applied on December 28, and the patient was able to be ambulatory. The

Fig. 3-A

Fig. 3-B

Fig. 3-A: Case 6, T. H. Preoperative bone defect of femur.
Fig. 3-B: Anteroposterior and lateral views, seven weeks after operation by the Type 2 procedure.

length of the defect bridged was two and one-half inches. Residual shortening of the right lower extremity amounted to five-eighths of an inch.

CASE 7. A private, twenty-two years old, was admitted on April 4, 1945. He had a healed compound wound of the left leg, and non-union associated with a bone defect involving the lower third of the left tibia, as a result of a severe shell-fragment wound incurred during enemy action in Sicily, July 16, 1943. Two

FIG. 4-A

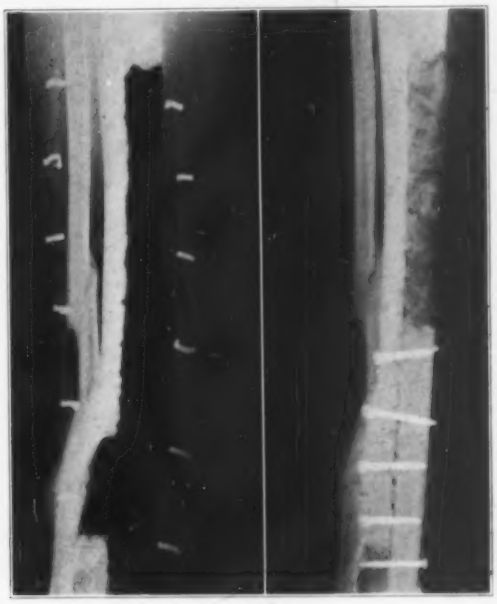

FIG. 4-B

Fig. 4-A: Case 8, F. B. Bone defect before operation.
Fig. 4-B: Roentgenograms taken during the operation show the steps of the Type 3 procedure with squaring of bone ends, removing massive half-cylinder grafts, rebedding grafts across defect, and filling residual donor defects with iliac chips.

FIG. 4-C

FIG. 4-D

Fig. 4-C: Anteroposterior and lateral views, three months after the operation.
Fig. 4-D: Anteroposterior and lateral views, six months after the operation.

sequestrectomies were performed elsewhere on November 2, 1943, and on February 24, 1944, and healing of the wound had occurred by August 1944. The scar was excised with primary closure on February 19, 1945. A modified reconstruction, which consisted of bridging of the defect with a half-cylinder graft and an apposing block of iliac bone, was performed on August 31. The hip spica was removed on December 5, and a toe-to-groin walking plaster was applied; at that time, union was clinically solid. The length of the defect bridged was two and seven-eighths inches. Residual shortening of the left lower extremity measured one-half inch.

FIG. 4-E

Anteroposterior and lateral views, eight months after the operation.

CASE 8. F. B., a private, thirty-four years old, was admitted on November 2, 1944. He had a draining compound wound, involving the right lower leg, and nonunion with a bone defect of the lower third of the right tibia, as the result of the explosion of a land mine near Florence, Italy, on July 1, 1944. Sequestrectomy was performed elsewhere on October 16, 1944. Saucerization was carried out on January 12, 1945, with healing of the wound by March 1. The scar was excised with primary closure on July 25, 1945 (Fig. 4-A). A reconstruction with apposing massive bone grafts was carried out on September 7, and the residual donor defect was filled with iliac-bone chips (Fig. 4-B). The hip spica was removed, and a toe-to-groin walking plaster was applied on December 5, at which time union was clinically solid (Fig. 4-C). The length of the defect bridged was two inches. Residual shortening of the right lower extremity measured one-half inch.

CASE 14. T. C., a sergeant, twenty-four years old, was admitted on June 15, 1945. He had a draining compound wound, involving the left lower leg, and nonunion associated with a bone defect which involved the left tibia at the junction of the middle and lower thirds, incurred when the patient was struck by exploding mine fragments, near Zerf, Germany, on March 17, 1945. Healing of the wound had occurred by August 28, 1945. Reconstruction with apposing half-cylinder grafts and filling of the residual donor defects with iliac chips were performed on December 5, 1945. The hip spica was removed and a toe-to-groin walking plaster was applied ten weeks after operation; at that time, union was clinically firm. Twelve weeks later (twenty-two weeks after operation), the plaster was removed; and union was found to be solid. A supporting toe-to-groin brace was applied. The length of the defect bridged was one and five-eighths inches. Residual shortening of the tibia measured seven-eighths of an inch.

SUMMARY

This report is based on the end results in the first eight cases, seven tibiae and one femur, treated by this method between December 15, 1943, and September 7, 1945. In all of these cases, bridging of the defects and union of the affected bones were accomplished successfully without the sacrifice of bone length. Since this time, similar procedures have been employed in thirteen additional cases (ten tibiae and three femora). Of the twenty-one patients operated upon, there were sixteen successful end results, one refracture twelve months after operation, and four failures due to recurrence of the infection after operation. Two of these failures resulted from infection, secondary to necrosis of scar tissue, adjacent to the operative field. In the other two cases of infection, drainage occurred postoperatively through the operative site. The case with refracture and the four cases of postoperative infection are classified as failures. In the twelfth patient operated upon, the complication of fracture of the sound portion of the proximal fragment of the femur at the site of the crosscut occurred during the operation. This was the result of abnormal leverage in the act of reducing the fragments. It necessitated the application of a lateral bone plate at the site of fracture, and prolonged the operative procedure considerably. Caution is advised, therefore, in the reduction of the fragments and rebedding of the grafts,

FIG. 5-A

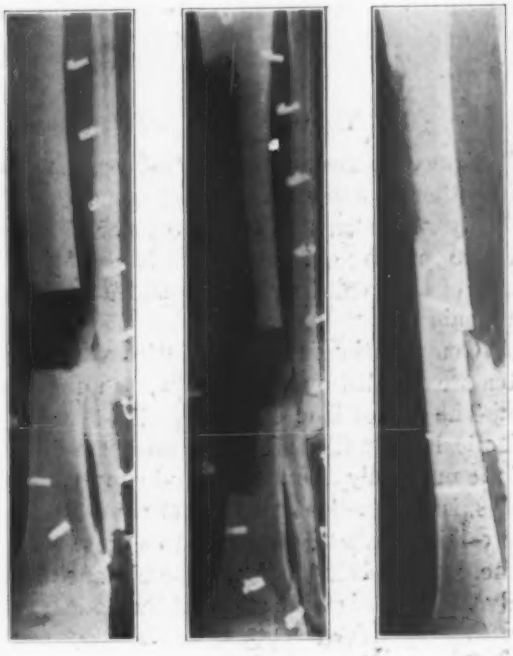

FIG. 5-B

Fig. 5-A: Case 14, T. C. Bone defect before operation.
Fig. 5-B: Roentgenograms taken during the operation show the Type 2 procedure with the steps of squaring of bone ends, removal of massive half-cylinder grafts, rebedding of grafts across defect, and filling residual donor defects with iliac bone chips.

FIG. 5-C

FIG. 5-D

Fig. 5-C: Anteroposterior and lateral roentgenograms, ten weeks after the operation.
Fig. 5-D: Anteroposterior and lateral roentgenograms, five months after the operation. The length of the defect bridged was one and five-eighths inches.

particularly in the femur, where the portion of the extremity distal to the fracture site is heavy and is under the control of an assistant during the manipulation necessary for reduction.

CONCLUSIONS

Apposing massive half-cylinder grafts, when firmly fixed, become integral parts of each other as well as of the host bone.

By reconstruction of the tubular architecture of the bone at the site of the defect, with supporting external cortex in the form of a cylinder and re-establishment of continuity of the medullary canal, solid union can be accomplished and tubular strength can be regained.

Complications associated with the removal of massive grafts from the unaffected tibia are avoided by this method, and unrestricted use of the sound extremity is possible.

The use of iliac bone to facilitate new-bone formation in residual donor defects is practical in the tibia; but does not seem indicated in reconstruction of the femur, because of the unusually abundant blood supply of this bone. Iliac bone, in the form of blocks or chips, is an excellent medium of osteogenesis for bridging bone defects in cases in which the original defect is too great to be repaired by apposing massive grafts from the affected bone. Emphasis is placed on the use of supplemental iliac bone in the bridging of defects only where rigid stabilization of the bone fragments is maintained by a single half-cylinder graft as a bed for the apposing iliac bone.

Preoperative reconditioning of the patient and of the affected extremity is considered to be equally as important in the final outcome as the reconstruction surgery itself.

These procedures seem applicable not only in the presence of large defects, but also in cases of non-union of the tibia and femur with small defects, caused by the interposition of fibrous tissue and sclerotic bone ends. In such cases, if the interposing fibrous tissue and sclerotic bone ends are removed, some shortening must result in bringing the bone ends into contact. This requires osteotomy of the fibula when the non-union is in the tibia. If the interposing fibrous tissue and sclerotic bone ends are not removed, the integrity of union must depend upon the onlay or inlay bone grafts. In these latter cases, bone-bridging develops only at the site of the graft. Refracture frequently occurs through this site of faulty union.

The length of the tibia or femur is the most important factor in determining the maximum length of defect which can be bridged by apposing half-cylinder grafts from the same bone. In the authors' experience, it was possible to bridge bone defects, ranging up to two and one-half inches in length, with apposing massive grafts. In defects greater than this, use of a single half-cylinder sliding graft and filling in of the opposite half of the defect with a block of iliac bone or with iliac-bone chips is advocated.

In the final analysis, successful bridging of defects with massive bone grafts depends on an adequate blood supply to the grafts and positive fixation of the grafts internally. By separation of the periosteum only at the site of the bone grafts to be removed, with the periosteum and muscle attachments left undisturbed on the sound portions of the shaft, an adequate blood supply is maintained for the successful revascularization of the grafts.

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DISCUSSION

Dr. James A. Dickson, Cleveland, Ohio: Major Flanagan and Captain Burem have made a real contribution to bone surgery and have demonstrated what can be accomplished by a well-planned and expertly executed procedure in bridging bone defects.

One might be a little skeptical about the end results following such extensive surgery in the involved bone, but the solid bony union with re-establishment of contour of the shaft of the bone and the consistently excellent results are striking and convincing testimony that their principles are sound. They have developed a very ingenious method of freeing the grafts from the host without interfering with the periosteum and the blood supply of the remaining portion of the bone, which principle, I am sure, plays an important role in their success.

In the last analysis, they are making use of the best features of the dual graft without interfering with the good leg, which, we must admit, has definite advantages.

After World War I, many attempts to bridge bone defects were carried out along the lines suggested by Hey Groves; but, due to the lack of suitable metal screws, the results were disappointing in many instances. Now that we have Vitallium screws to assure positive internal fixation, and chemotherapy, together with this method of preserving a good blood supply in the host fragment, excellent results are the rule rather than the exception, as Major Flanagan and Captain Burem have so ably demonstrated.

I certainly agree with them that the preoperative reconditioning of the patient and of the affected extremity is most important, and I am sure this played no small part in the excellent results they obtained.

It has been a great pleasure indeed to have had the opportunity of discussing their paper, and I feel that Major Flanagan and Captain Burem have demonstrated the application of very sound principles and are to be congratulated on their excellent piece of work.

CALCIFIED MEDULLARY DEFECTS IN BONE

BY ALBERT BARNETT FERGUSON, JR., M.D., BOSTON, MASSACHUSETTS

From the Surgical Clinic of the Peter Bent Brigham Hospital, Boston

The presence of a symptomless, solitary, rounded mass of irregular nodules of amorphous calcification within the medullary cavity of a long bone has been mentioned, but not adequately described, in the medical literature. Such lesions, incidentally noted during the roentgenographic examination of the neighboring joint, are sometimes confusing, and clarification of their clinical and roentgenographic features is needed.

ROENTGENOGRAPHIC APPEARANCE

Calcified medullary defects of bone appear as solitary, rounded areas, made up of irregular nodules of amorphous calcification, in or near the metaphyseal regions of the long bones. They are frequently located in the center of the medullary cavity and are of variable size,—usually one to two centimeters in diameter. When these areas are larger, they are likely to be confused with caisson disease in bone. The nodules are of even calcific density. The periphery of the lesion reticulates with the normal bone lines, but is sharply demarcated from normal bone structure. There is no central area of lesser density and no shell of calcification. There is no expansion of the shaft of the bone, and lesions do not extend into the cortex. This combination of positive and negative features is typical of calcified medullary defects, and differentiates them from other bone lesions of somewhat similar appearance. Figure 1 shows a typical lesion in the lower portion of the femur, while Figure 2 is a lateral roentgenogram from another case, showing a somewhat larger lesion. A calcified medullary defect located in the greater trochanter is shown in Figure 3. So little disturbance of medullary structure is produced that, apparently, these lesions are visible

FIG. 1

FIG. 2

TABLE I

DISTRIBUTION OF NON-OSSEOUS DEFECTS

	Number of Patients	Per Cent.
Distal portion of femur	25	59.5
Proximal portion of tibia	6	14.3
Proximal portion of femur	3	7.1
Proximal portion of humerus	3	7.1
Wing of ilium	2	4.8
Patella	1	2.4
Proximal portion of fibula	1	2.4
Vertebra	1	2.4
Total	42	100.0

only after they have become calcified. This is in contradistinction to lesions such as Schmorl's nodes.

DISTRIBUTION

Histories and roentgenograms of cases noted in private practice were secured through the courtesy of Louis G. Howard, M.D. Statistics on the distribution of calcified medullary defects were secured from an additional thirty-one cases. A total of forty-two cases were examined roentgenographically, and the distribution of these lesions is summarized in Table I. Their predilection for areas where skeletal growth is greatest was noted, with the distal portion of the femur the site of 59.5 per cent. of the lesions.

Typically, these lesions are solitary; but in one case, when the wing of the ilium was involved, the occurrence was bilateral; and in another case a lesion was found both in the wing of the ilium and in the neck of the femur.

CLINICAL DESCRIPTION

None of these patients complained of pain that could be ascribed to the area occupied by the calcific bone mass. All the patients were in the age group of forty years and over, with the exception of a veteran, aged twenty-four.

Three of these patients were subjected to a clinical and roentgenographic follow-up of from six months to two years. In that period they remained symptomless, and no changes in the roentgenographic appearance occurred.

In all cases the lesions were found during the search for pathological changes in the neighboring joint. These pathological changes ran the gamut of orthopaedic conditions and included such lesions as tuberculosis, coxa plana, and degenerative arthritis.

DIFFERENTIAL DIAGNOSIS

The fact that this lesion is symptomless helps to distinguish it from the following diseases in which other pathological changes are involved:

Caisson Disease of Bone: The occupational history and the presence of some pain are characteristics of this condition. Roentgenographically, the lesion is not uniformly dense, but appears as irregular areas of translucency and will frequently be found in conjunction with arthritis of the neighboring joint. A thin band of calcification surrounding the area is not uncommon.[1] This was not seen in cases of calcified medullary defects. The distribution of the lesions in caisson disease is often multiple rather than solitary, and may involve the mid-shaft of the bone. As a rule, the bone involvement is much more extensive than that of the calcified non-osseous defects.

Chondrodysplasia: Since medullary defects are felt to be a form of faulty development of bone from cartilage, such lesions may properly be classed under this broad heading. Occasionally, calcified bone defects are noted in conjunction with the typical familial type of chondrodysplasia with characteristic expansion of the shaft in multiple and symmetrical locations.

Osteoid Osteoma: These lesions may, occasionally, have a superficial resemblance to calcified medullary defects. In these cases, the osteoma is highly ossified and is located in the metaphyseal region,—a rare location for it. In the center of the dense sclerosis the lesion contains an area of translucency, which is not seen in the developmental defects. The pain and tenderness, which are associated with this lesion, help in its differentiation.

Sclerosing Osteogenic Sarcoma: There is definite pain, often quite severe, with this lesion. Instead of being sharply demarcated by roentgenogram, the lesion characteristically fades away into the normal bone structure, often with cortical invasion. Occasionally in the early stages of this disease, particularly when it involves the proximal portion of the tibia, the resemblance to calcified medullary defects of bone may be marked. The sarcoma, however, will be found abutting on the cortex somewhere along its periphery. This aids in its diagnosis.

Osteoplastic Prostatic Metastases: Pain is frequent in these lesions, but they may be confused with developmental medullary defects. The history and physical examination may be significant. These lesions are usually multiple, more widespread, characteristically in the pelvis, and usually are not so dense as calcified medullary defects. When multiple, their tendency toward a circular, rather than a rounded, nodular structure is evident. There may be loss of normal bone structure surrounding the lesion, and the density is extremely variable. Osteolytic lesions may be noted in conjunction with osteoplastic metastases.

Bone Infarcts: As described in the literature[2], these lesions have a distribution similar to calcified medullary defects and are similar to caisson disease, although an occupational history may not be obtained. Roentgenographically, these lesions may appear to involve

FIG. 3

FIG. 4-A

Fig. 4-A: Calcified defect removed intact at open reduction of accompanying fracture.

articular cortex. They contain cystic areas of translucency and often are surrounded by a thin wall of calcification. Their density is not even. There is often an associated arthritis.

FIG. 4-B

Low-power photomicrograph taken at the periphery of the lesion. *a* indicates calcified cartilaginous matrix; *b*, bone spicule; *c*, attached area of viable cartilage.

FIG. 4-C

High-power photomicrograph from the center of the lesion. *a*, cartilaginous matrix; *b*, area of viable cartilage.

CASE REPORT

Through the courtesy of Carl W. Walter, M.D., it was possible to procure a section of a calcifying developmental defect for biopsy. This lesion was noted incidental to a spiral fracture of the distal third of the right femur.

T. F., a white male, sixty-eight years old, a stationary engineer, never engaged in construction work, entered the Peter Bent Brigham Hospital with a spiral fracture of the middle and distal thirds of the right femur, following a fall on getting out of bed. A calcified developmental defect was found in the distal section of the fractured bone. Figure 4-A, taken on admission, shows this lesion with the associated fracture.

At open reduction, this calcified area was removed, apparently intact and easily separated from the adjacent bone, leaving a round defect where it had been nesting. Postoperative roentgenograms revealed that the lesion had been removed except for two small flecks of calcification. The lesion consisted of reddish tissue, irregularly shaped into a rounded mass, approximately one centimeter in diameter and two centimeters in length, and containing hard yellow areas. It was found to be glassy hard and rang when dropped on a hard surface.

Sections revealed a somewhat irregular area of calcified, non-viable cartilage, at the periphery of which a slow process of new-bone formation was taking place. Figure 4-B is a low-power photomicrograph taken at the periphery of this lesion. It shows all features of the lesion, from calcified cartilaginous matrix on the left to bone spicules with small attached areas of viable cartilage on the right. A high-power photomicrograph of the cartilaginous matrix with an area of viable cartilage is shown in Figure 4-C.

DISCUSSION

There is no evidence that this lesion is expansile or has any power of autonomous growth, and it cannot be classed as an enchondroma. Its location is in keeping with other cartilaginous disturbances of bone formation; and, as an example of faulty development of bone from cartilage, it may be classified as one of the many forms of chondrodysplasia.

The pathological and clinical findings lead one to the conclusion that this lesion is a degenerated calcified island of cartilage, which did not progress to complete ossification at the time of skeletal growth.

The solitary, non-symmetrical nature of this lesion supports the contention that trauma may be an etiological factor. Rickets may also be mentioned in connection with this lesion.

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IMMOBILIZATION WITH BONE GRAFTS IN THE TREATMENT OF TUBERCULOSIS OF THE JOINTS AND POTT'S DISEASE *

BY PROFESSOR ETIENNE SORREL AND MADAME SORREL-DEJERINE, PARIS, FRANCE

In 1920, when the use of bone grafts for immobilization in the treatment of Pott's disease was first begun in France, the method was new to us and untried. Although Albee had already performed the operation in the United States, and his technique had been fully described, his operative method had been severely criticized. Favorable results did not seem to follow the few trials made in France before 1914; and, during the long years of World War I, interest in the perfection of the technique, of necessity, waned. However, after 1918, interest in bone grafts was revived, and a great deal of study was devoted to their successful use.

From the first, it was realized that fixation of the diseased vertebrae by a bone graft, although not universally applicable to all cases of Pott's disease, would give excellent results under certain well-defined conditions. By analogy, the same method could be applied in treating tuberculosis of the other joints. Some good results ensued; in other cases, however, the results were not so good as those obtainable by methods already in use.

In short, in this paper, the writer is attempting to sum up from his own long experience the progress which has attended bone-grafting in the treatment of joint tuberculosis over the years.

Fixation by bone graft certainly must not be performed routinely in all cases of joint tuberculosis. There are two reasons why it is only rarely indicated for children: first, because often cures may be effected, especially in young children, leaving them with good joint function and in better condition than if the joint had been blocked by a graft. In producing true bony ankylosis, two bare and ulcerated bones must be brought into direct contact. In children the epiphyses are for some years formed of a bony nucleus imbedded in cartilage, and such tissue is unfavorable ground for the development of tuberculosis. It frequently happens that with the passage of time the articular ends remain, if not intact, at least not completely destroyed; and some cartilaginous tissue remains to prevent bony fusion. On the other hand, in children suffering from Pott's disease, there often occurs a fusion of the diseased vertebrae, which results in a cure as definite as that brought about by the use of a graft.

The second and even more important reason why grafts are not often indicated for children concerns the growth of the skeleton. For example, to immobilize a knee joint, the bone graft must act as a bridge from femur to tibia over the epiphyseal cartilage. As the femur and the tibia grow, the bone graft, which does not stretch, may break or pull away from its points of insertion, or, if it holds, genu recurvatum, genu valgum, or genu varum may develop, conditions which are difficult to correct. The same situation holds true, not only for all bone grafts in the other articulations, but also for those in Pott's disease.

If shorter grafts are used which dovetail the two bony extremities, and pass through the epiphyseal cartilage, the results are even more unsatisfactory, for to the deformity of the limb there are added other problems of growth. In other words, success in the use of a graft can be looked for only when growth has almost ceased.

Further consideration of the possibilities for treatment of tuberculosis of the joint after growth has stopped leads to the conclusion that measures other than bone grafts are often satisfactory without being harder on the patient or more difficult for the surgeon. Except in a few special cases, it seems unnecessary to substitute immobilizing grafts for other treatment.

* Read at the Annual Meeting of The British Orthopaedic Association, London, October 18, 1946.

For instance, it is useless to attempt arthrodesis of the upper extremity in an adult by using a graft. The primary objectives are to cure the lesions and, at the same time, to preserve as much as possible the mobility of the joint. Both of these ends can be obtained by resection.

For joints of the lower limb, there are hardly any indications for arthrodesis by grafting, except in the hip. Resection of the knee gives excellent results. Of course, after a certain age, resection can no longer be done, because fusion would not be good; but in these cases, bone grafts have little better chance of a successful outcome. In the ankle joint and in the tarsus, resection is the better procedure, although the results are often uncertain.

In the final analysis, it would seem that the use of bone grafts in the treatment of tuberculosis of the joints has been overdone in recent years; and we are forced to admit that their use should be limited.

There still remains a wide field for the bone graft,—namely, in the two most frequent and most serious adult tuberculous affections: Pott's disease and disease of the hip joint. In fact, before the use of the bone graft, no successful operative treatment for these conditions was available. Resection of the hip, although easily performed, gave unfavorable results; and in tuberculosis of the spine, direct operations on the focus of infection seemed inconceivable.

Non-operative treatment gave deceptive results in both affections among adults, so that until about 1920, hip disease and Pott's disease were considered very serious, and in both cases the prognosis was grave. The use of bone grafts certainly brightened the picture. The large number of cases operated upon, as well as the length of time which has passed since operation, enables us to recommend the measure.

In tuberculosis of the spine, bone grafts have been done most frequently and over the longest period of time. The writer has practised this procedure for twenty-six years; and, although the exact number of cases is unavailable, it must be close to 500.

Precautions should be taken both before and after the operation. We think it inadvisable to operate upon a patient at the onset of Pott's disease, when the disease is actively developing and showing disquieting general phenomena with fever, loss of weight, and intense pain, or when an abscess or a paraplegia has recently appeared. It is better to wait until the lesions are stabilized and until the patient has in some way given proof of his capacity to withstand the disease. In fact, it is often well to immobilize the patient before operation, and to recommend rest in the mountains or at the seashore.

After the operation has been performed, the patient should be immobilized for about six months, because the bone graft must have sufficient time to become solidly fused with the spinous processes, so that it can play the role expected of it. Walking should be started very gradually, and the patient should wear a plaster jacket.

The belief that a cure of Pott's disease may be obtained by placing of a bone graft early in the disease, and then allowing the patient to resume normal life after some weeks in bed, is unfounded. This mistake was made when the method was first used; but, because the results were so uncertain, the use of the graft was abandoned. However, during the past two decades, since we have realized the importance of exercising great care, grafts have been used more and more. Proceeding in this prudent way, associating surgical with general treatment, we have obtained excellent results in Pott's disease in adults. Cures are usually stable and definitive, and the patients are able to take up a really active life once again without any reappearance of the disease, contrary to our experience with non-operative methods. We have seen, for instance, a great number of women undergo completely normal pregnancies after such an operation, and this would seem to be a demonstrative proof.

An important question arises as to the age at which these grafts can best be used. As we have said, there are few indications among children. It is only when the child becomes an adolescent, and when fusion of the diseased vertebrae fails, that grafts should be uti-

lized. Furthermore, they may be used until the patient has reached a fairly advanced age. One of our patients was fifty-eight when a graft was first applied for a very serious case of Pott's disease, localized in the thoracic region. This patient resumed active life a year later. After ten years he underwent prostatectomy. He is now seventy-eight years old, and is very well.

Another one of our patients, a physician, was sixty-three at the time the graft was applied for Pott's disease in the cervical region. This patient has remained perfectly well ever since.

Wherever Pott's disease may be localized—in the cervical, thoracic, or lumbar regions —the technique is about the same, differing only as there exists or does not exist a marked kyphosis.

If kyphosis exists, it is better to take a flexible graft from the tibia with the hammer and chisel. This graft will adapt itself better than the rigid graft to the curve of the kyphosis. If kyphosis does not exist, it has been found that the rigid graft, taken with the double electric saw from the tibia, according to the method of Albee, is the best. The over-all result is the same, and whether the graft is rigid or flexible, it provides complete immobilization.

For hip disease in adults, arthrodesis with the use of grafts has modified the formerly grim prognosis. We have operated upon a great number of patients with hip disease during its development; and, judging from the time which has elapsed since the first operation, we feel that the results may be called satisfactory.

In the report which we presented in London in 1933 at the Congress of the International Society of Orthopaedic Surgery, we pointed out that at that time we had already seen seventy-five of our old patients, twenty-nine of whom had been operated upon from two to six years previously. The number of patients operated upon has increased considerably. Thirteen years have passed, and the results have demonstrated the success of the operation.

As with Pott's disease, prudence must be exercised, and the patient should be operated upon only when the general and local conditions allow it. One of the most important lessons for the surgeon dealing with active hip disease is that of learning to wait before operating, while carrying out preliminary general treatment. After the operation, complete immobilization in plaster is necessary for a minimum of three months, and sometimes for six.

Arthrodesis with a graft for active hip disease cannot be done on young children for the reasons already mentioned, but can be employed from the thirteenth or fourteenth year to a fairly advanced age.

One of our patients was fifty and, although her hip disease was of a severe form, she could walk again three months after the operation, and is now, at sixty, very well.

Another patient was fifty-six. After being immobilized for three months, she took up active life. During a period of eight years, we continued to hear that she was well, but during the War we lost track of her.

Another patient fractured her graft in the course of a bad fall. This graft united very well. We have seen other similar examples which prove the viability of these grafts, and the confidence which one can have in them.

In cases where arthrodesis is performed during the progress of hip disease, a well-defined technique should be followed:

The graft should be placed at a certain distance from the diseased joint. We have found that the technique giving best results uses the extra-articular graft, which is taken with the electric saw from the tibia, and which is placed so as to unite the wall of the ilium and the trochanter by a fixed bony bridge.

Like the vertebral grafts in Pott's disease, these iliotrochanteric grafts in hip disease give admirable results. They fuse solidly at their extremities in the iliac wall and in the trochanter. They develop and grow larger. After some months, they result in absolute im-

mobilization, under the protection of which it is safe to allow the patient to resume walking gradually. As time passes, the graft strengthens. Roentgenograms of grafts taken some years after their application always astonish physicians, who have hitherto been adherents of the old classic dicta that grafts live only with difficulty and have a tendency to be absorbed.

After hip disease has run its course, grafts can still render great service by fixing the hip in good position, enabling the patient to walk better, and preventing reactivation of the infection. It is a reconstructive operation, devised for cured lesions. Above all, it is indicated for children, in whom one sees great destruction of bone. The extra-articular graft placed as a bridge from the ilium to the trochanter would break or tear its insertions during growth; so we must have recourse to a different procedure. For a long time we have combined an intra-articular and extra-articular arthrodesis, which we have called mixed arthrodesis. After having opened wide the joint, we scrape the articular surfaces. Then, with a graft taken from the wall of the ilium or from the tibia, we join at the same time the cotyloid rim, the head, and the neck of the femur to the level of the greater trochanter. Thus is formed a solid bony block, and the growth of the femur is not hindered.

In conclusion, it seems to us that, among adolescents, adults, and aged people, immobilization grafts have been of great help in the treatment of tuberculosis of the joints; and in two of its most frequent and most severe localizations, in the spine and the hip, end results have been greatly improved by bone grafts. Among children, the use of grafts has brought only slight modifications in the treatment of Pott's disease and tuberculosis of the joints. However, in the sequelae of hip disease these immobilization grafts have been found to be extremely useful.

FUNCTIONAL ASPECTS OF THE ABDUCTOR MUSCLES OF THE HIP *

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INTRODUCTION

The glutaeus medius limp is characteristic and familiar to most physicians. To the orthopaedic surgeon it presents a problem which is easy to understand, but difficult to solve. To date no surgical procedure has been devised, either in the form of muscle transplantation or osteotomy, which will improve adequately the function of a hip deprived of its abductor muscles. In addition, a study of patients who have suffered paralysis of the abductor muscles in infancy discloses that the growth of the proximal end of the femur is altered on the involved side. The normal angulation of the femoral neck fails to develop, and coxa valga results.

Before any surgical procedure for the improvement of hip function can rest on an altogether sound physiological basis, or an explanation can be offered for the alterations in the growth of the femoral neck, a knowledge of the forces acting about the hip joint should be available. The most important forces appear to be those related to the pull of the abductor muscles, and further study of their function seems warranted.

Furthermore, a knowledge of the direction and magnitude of these forces greatly illuminates certain features, not only in the etiology of coxa valga, but also in that of malum coxae senilis, as well as pointing to the significance of the fascia lata and some of the effects of its shortening.

An attempt has been made to simplify this complex problem by considering it to be purely one of statics, and to discuss forces only in two dimensions. While it is realized that this is a three-dimension problem, only the static forces acting in the frontal plane of the body will be considered in this investigation.

It is apparent that the measurements of the forces developed by the abductor muscles in the living subject cannot be obtained directly, so that an indirect method must be employed. In this study, the method has consisted of the following steps:

1. Theoretical calculation has been made of the torque about the hip, when the subject is bearing weight on one extremity.
2. The value of the theoretical torque is checked experimentally.
3. When a determination has been made of the value of the torque which the abductor muscles must resist, the pull on the individual muscles and tendinous structures may be calculated.

THEORETICAL TORQUE ABOUT THE HIP JOINT

The minimum theoretical value of the torque about the hip, due to the center of gravity of the body being medial to the center of rotation of the hip joint when weight is borne on one extremity, is readily ascertained. Since the center of gravity necessarily lies in the median sagittal plane, the torque is the product of the body weight and the distance from the median sagittal plane to the center of rotation of the femoral head (Fig. 1). At first glance, it may appear that such an estimate of the torque is erroneous, because the mass of the limb upon which the weight of the body is being carried is below the level of the hip joint, and should be deducted from the weight of the entire body. If, however, the center of gravity of the supporting lower extremity can be shown to lie in

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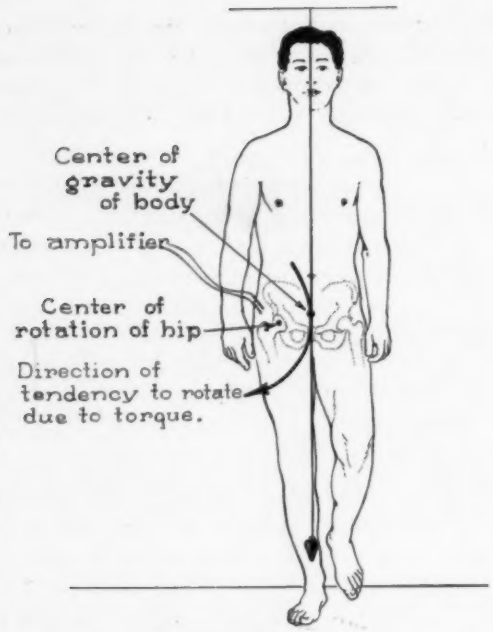
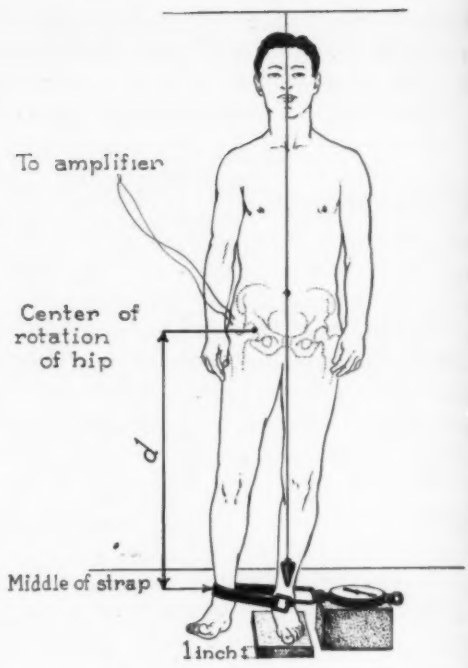


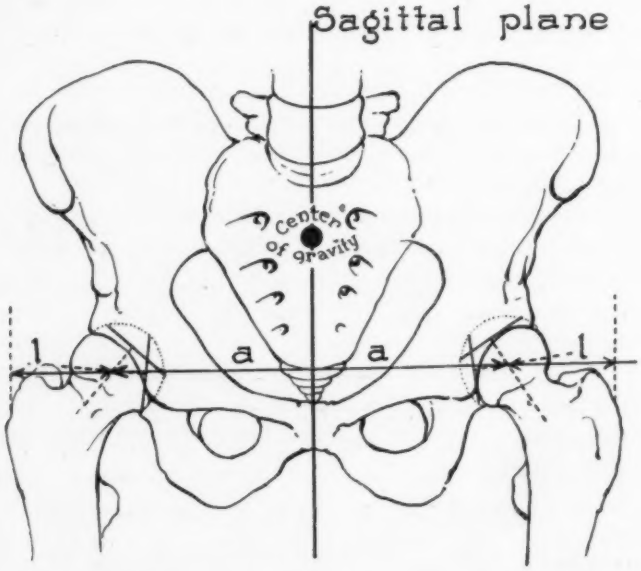
Torque = Weight of body x distance from center of rotation of hip to sagittal plane of body.

FIG. 1



Torque = d x scale reading

FIG. 2



a = distance of center of rotation of femoral head to sagittal plane of body
Minimal Theoretical Torque = W (weight of body) x a

FIG. 3

Showing how value of torque is estimated.

the same vertical plane as the center of rotation of the hip joint, then this method of calculating the torque is not in error, because the weight of the supporting limb can exert little or no torque and can consequently be neglected. On the other hand, the extent to

which the center of gravity of the supporting extremity deviates from the vertical plane passing through the center of rotation of the femoral head will influence the validity of the calculations; and an attempt must be made to measure the magnitude of this deviation.

The center of gravity of the lower extremities of six cadavera, which had been amputated by the guillotine method through the center of the hip joint, was determined by the familiar method of suspending the extremity in two positions. It was found that the center of gravity in a horizontal plane lay approximately two thirds of the distance from the heel to the hip joint (60.47 per cent. ± 1.17 per cent.), and just medial to the shaft of the femur in the vertical plane. When these data were applied to living subjects, the approximate center of gravity was marked on the thigh; and a plumb line was dropped from a point over the femoral head to the floor. It was found that, in the experimental position, the center of gravity of the extremity did not deviate from the plane of the plumb line more than 1.5 centimeters. Because of this small deviation, it was felt that the assumptions made for the theoretical torque, utilizing the total body weight without correction, were justified.

The minimum theoretical torque was calculated on thirty-five normal individuals (eighteen males and seventeen females) between the ages of nine and fifty-one. In order to determine the center of rotation of the femoral head and the length of the lever arm, roentgenograms of the pelvis of each subject were taken at a distance of six feet. The center of rotation was found by dropping a series of perpendiculars through the mid-points of chords constructed in relationship to the circumference of the femoral head. The distance so established between the center of rotation of each hip joint was measured in centimeters and divided by two, thus providing the distance from the median sagittal plane of the body to the center of rotation of each femoral head (Fig. 3). The subjects were weighed to the nearest tenth of a kilogram. The minimum theoretical value of the torque was then found by multiplying the body weight by the distance from the median sagittal plane to the center of rotation of the hip joint, and expressing the value in kilogram-centimeters.

The magnitude of the torque in kilogram-centimeters was discovered to be, in males, 10.00 ± 0.86 times the body weight in kilograms; and, in females, 9.4 ± 0.97 times the body weight in kilograms.

After these values had been obtained, it was considered desirable to employ some method of checking empirically the theoretical calculations. This was done by the following method, the same subjects being utilized so as to permit a comparison of the value of the theoretical and the experimental torque in each instance.

TORQUE DETERMINED EXPERIMENTALLY

The determination of the experimental values of the torque about the hip joint on the weight-bearing side was based upon myographic recordings. Both skin and needle electrodes were utilized. The electrodes were placed in or over the tensor fasciae femoris, the glutaeus medius, and the glutaeus minimus. The action currents were amplified by means of the Grass electro-encephalograph, and the output was passed through a voltage integrator to facilitate the estimation of the electric potentials.

The action potential was obtained as the individual bore all his weight on the limb to which the electrodes were applied. The opposite extremity was flexed at the hip and the knee, just sufficiently to clear the floor. The abductors necessarily contracted to keep the pelvis level and the degree of contraction was recorded by means of the myograph.

The recorded action potentials so obtained from the abductors were translated into the rotatory force (torque in kilogram-centimeters) exerted by these muscles as they acted to maintain the pelvis level by plotting an experimentally determined force curve, the ordinate indicating the action potential and the abscissa the torque in kilogram centimeters. The loci were determined in the following manner:

Without disturbing the position of the electrodes or the settings of the amplifiers, and without grossly altering the position of the subject, the weight was transferred to the opposite limb. A small block was placed under the foot so that the extremity from which the recordings were taken just cleared the floor without the necessity of flexing either the hip or the knee. The distance between the heels of the two feet was kept at less than five inches. Around the ankle at the level of the lateral malleolus was placed a strap, to which was fastened a spring scale whose excursion was very small. The elongation of the spring was less than one centimeter when the scale registered from zero to fifty kilograms. The location of the femoral head was marked on the anterior aspect of the groin, as determined by palpation of the femoral artery just distal to the inguinal ligament. The distance from the femoral head to the middle of the strap about the ankle was measured in centimeters. The power of abduction could be measured accurately and expressed as a rotatory force in kilogram-centimeters by multiplying the distance from the center of rotation of the femoral head to the leather strap by the reading on the spring scale (Fig. 2). Simultaneously, the action potential of the contracting abductors could be recorded. From four to eight loci were plotted from zero to the maximum power of abduction, and were connected by means of a smooth curve. From the graph could be obtained the value of the torque at any known action potential. The action potentials of the abductor muscles of the hip, when the patient was bearing weight upon one lower extremity, could be translated directly into moments of force (torque). From the graphs of each subject (Fig. 4), the experimental torque so obtained could be compared with the theoretical torque determined previously.

The values for experimental torque, taken with the pelvis level, were consistently lower than the calculated values for theoretical torque. The disparity between the two

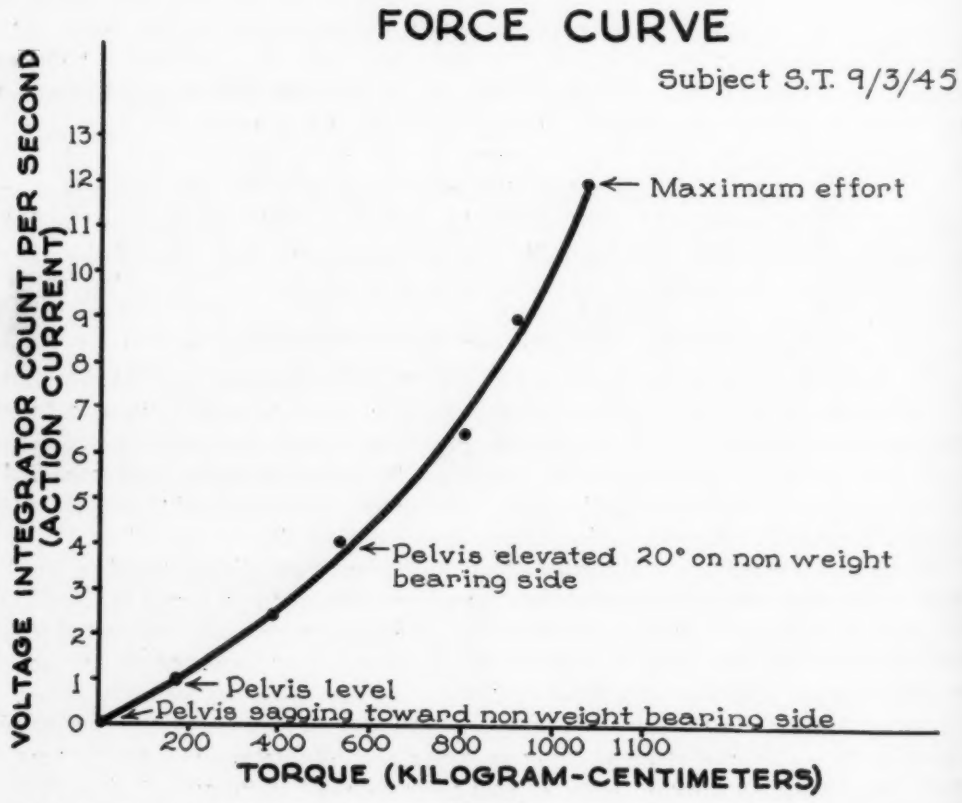


FIG. 4

A typical force curve, relating torque to action potential of abductor muscles.

values was sufficiently great to indicate that factors other than those already taken into account were responsible. The experimental torque, in general, was about one third to one half lower than the corresponding values for the theoretical torque. Further investigations were undertaken to determine the cause of these differences.

The original subjects were studied again but, instead of limiting the myographic recordings to the position where the pelvis was held level while the subject was bearing weight upon one lower extremity, additional recordings were secured as the pelvis was elevated approximately 15 degrees on the non-weight-bearing side and as it was permitted to sag on the non-weight-bearing side until the subject felt completely relaxed. Usually the angle of pelvic sag was about 10 to 20 degrees. In this way, it was felt that the full contraction of the muscles could be recorded without the possible limiting effect of rigid connective-tissue structures, such as fasciae and ligaments, and that the precise influence of these structures could be detected.

As the pelvis was elevated, the action potential of the abductors increased until the experimental torque agreed very closely with the theoretical torque. As the pelvis was permitted to sag, the action potentials gradually decreased until, at a position between 10 and 20 degrees of pelvic tilt, a posture was reached which could be maintained with little or no muscle contraction, as indicated by the action potential. Palpation of the thigh with the pelvis in the sagging position, however, indicated that the fascia lata was tense. The pelvis apparently was prevented from further depression almost entirely by ligamentous pull.

In addition to these observations, the maximum pull of the abductors, expressed as torque (kilogram-centimeters), was calculated for each individual. The results calculated from these data and the conclusions drawn from these results are given below.

COMPARISON OF THEORETICAL AND EXPERIMENTAL TORQUE AND LIMITING FACTORS

The average difference between the theoretical torque and the experimental torque is 9.3 ± 5.7 per cent. for the males, and 8.9 ± 4.9 per cent. for the females. The actual magnitude of the torque in kilogram-centimeters, as established both theoretically and experimentally, is approximately ten times the body weight in kilograms.

It is quite apparent that, when the subject is standing on one extremity with the pelvis level, the force which prevents the pelvis from rotating about the supporting hip is not due entirely to muscle pull. A considerable amount of force is contributed by passive tension on the fascia lata and the iliotibial tract. To cause the passive tension of the ligamentous structures to become slack and to make the muscles alone maintain the full load requires elevation of the opposite buttock and a pelvic tilt of approximately 10 or 15 degrees toward the side of the weight-bearing extremity. As the pelvis is depressed toward the non-weight-bearing side, the fascial structures become increasingly taut and assume a greater and greater degree of the total force, until a point is reached where little or no muscle contraction is required.

After force curves (Fig. 4) have been plotted for each experimental subject, further information can be determined from them. The torque produced by muscle contraction alone, for the three positions of the pelvis, can be read directly from the graphs. The ratio of muscle used to the total muscle power available can be calculated readily. While there are wide individual variations, due to such factors as the shortness of the iliotibial tract and the degree of muscle development, average values have been calculated for the series. The extent of the variation is indicated by the size of the standard deviations. The quantitative data are given in Table I.

The importance of the fascia on the outer portion of the thigh now becomes apparent and, furthermore, helps to explain the great disparity which exists between the mass and size of the abductors, excluding the glutaeus maximus, as compared with that of the adductors, which contribute but a small part toward maintaining the parallelism of the pelvis. The actual combined mass of the glutaeus medius, the glutaeus minimus, and the

TABLE I

DETERMINATION OF TORQUE ABOUT THE HIP JOINT WITH PATIENT BEARING WEIGHT ON ONE EXTREMITY

Case No.	Patient	Age (*Years*)	Weight (*Kilograms*)	Torque (Kilogram-Centimeters)					A	B	C	D
				Calculated Torque (T)	Experimental Values of Torque Obtained from Myographs							
					Pelvis Sagging * (S)	Pelvis Level (L)	Pelvis Elevated * (E)	Maximum Effort (M)	$\frac{T-E}{T} \times 100$ (*Per Cent.*)	$\frac{E}{M} \times 100$ (*Per Cent.*)	$\frac{S}{E} \times 100$ (*Per Cent.*)	$\frac{L}{E} \times 100$ (*Per Cent.*)
						MALES						
1	R. D.	51	59.8	562	49	175	523	1042	6.9	50.2	9.4	33.5
2	M. M.	29	69.5	690	36	252	672	1262	2.6	53.2	5.4	37.5
3	C. B.	34	82.0	732	96	650	855	1923	16.8	44.5	11.2	76.0
4	A. C.	27	62.5	670	70	274	612	1141	8.7	53.6	11.4	44.8
5	W. P.	26	76.2	700	0	685	746	1195	6.6	62.5	0	91.8
6	J. S.	43	83.0	905	206	629	990	1649	9.4	60.0	20.8	63.5
7	V. I.	38	80.0	780	38	232	718	1541	7.9	46.6	5.3	32.3
8	M. C.	22	69.2	620	45	375	600	975	3.2	61.5	7.5	62.5
9	J. E.	25	84.0	880	188	458	830	1352	5.7	61.4	22.6	55.2
10	J. C.	23	78.5	760	75	466	714	2040	6.1	35.0	10.5	65.3
11	P. D.	29	89.1	856	94	529	773	1319	9.7	58.6	12.2	68.4
12	W. M.	22	77.7	760	0	457	761	1423	0.1	53.5	0	60.1
13	A. M.	21	67.7	617	0	320	552	923	10.5	59.8	0	57.9
14	B. L.	23	74.9	692	0	144	648	1220	6.3	53.1	0	22.2
15	C. L.	22	77.1	771	0	340	620	1080	19.6	57.4	0	54.8
16	D. H.	50	66.4	624	19	296	558	890	10.5	62.7	3.4	53.0
17	S. L.	25	76.5	743	60	194	575	1008	22.6	57.0	10.4	33.7
18	R. I.	14	49.2	382	75	248	324	720	15.2	45.0	23.1	76.5
Averages									9.3	54.2	8.5	54.9
Standard deviation									± 5.7	± 7.3	± 7.4	±17.9

Averages Standard deviation									9.3 ± 5.7	54.2 ± 7.3	5.8 ± 7.4	±17.9

TABLE I (*Continued*)

FEMALES

19	A. S.	12	47.2	410	0	255	405	682	1.2	59.4	0	62.9
20	M. S.	9	32.9	224	34	163	250	430	11.6	58.1	13.6	65.2
21	M. S.	25	51.7	517	17	260	470	865	9.1	54.3	3.6	55.3
22	R. T.	27	59.0	565	56	522	615	1120	8.9	54.9	9.1	84.9
23	S. B.	34	67.6	695	19	224	670	860	3.6	77.9	2.8	33.4
24	W. K.	23	61.7	617	0	312	559	700	9.4	79.9	0	55.8
25	J. C.	20	50.5	482	0	280	460	670	4.6	68.6	0	60.9
26	J. H.	23	55.2	490	17	240	460	1125	6.1	40.9	3.7	52.2
27	D. L.	28	63.5	585	38	568	618	1100	5.6	56.2	6.1	91.9
28	M. L.	25	63.5	585	35	322	553	992	5.5	55.7	6.3	58.2
29	I. I.	34	60.0	568	0	225	430	620	24.3	69.4	0	52.3
30	H. M.	29	68.0	610	0	87	540	860	11.5	62.8	0	16.1
31	L. G.	25	62.6	570	104	273	512	850	10.2	60.2	20.3	53.3
32	A. K.	27	69.3	678	140	574	755	1301	11.3	58.0	18.5	76.0
33	S. T.	21	62.9	592	37	188	527	1052	10.9	50.1	7.0	35.6
34	M. K.	25	61.3	613	20	294	580	1240	5.4	46.8	3.4	50.7
35	V. L.	22	66.0	600	106	411	528	709	12.0	74.4	20.1	77.8
Averages Standard deviation									8.9 ± 4.9	60.4 ±10.3	6.8 ± 6.8	57.7 ±18.2

* Elevation on non-weight-bearing side of 15 to 20 degrees.

A = Percentage differences between the values obtained for the theoretically calculated torque and for the experimentally determined torque.

B = Percentage of the maximum torque possible due to muscular effort, which is required to hold pelvis elevated on non-weight-bearing side.

C = Percentage of muscle contribution to total torque required when pelvis is permitted to sag.

D = Percentage of muscle contribution to total torque required when pelvis is held level.

tensor fasciae latae constitutes only 15.3 per cent. of the entire muscle mass about the hip joint. A great muscle mass is unnecessary in the abductors, because of the role played by the fascia in assisting and sparing these muscles.

THE ACTION OF THE ABDUCTOR MUSCLES

After the magnitude of the torque about the hip joint has been determined, as the center of gravity of the body lies medial to the center of rotation of the hip, it becomes possible to calculate the minimum pull of the abductor muscles and the amount of tension exercised by the iliotibial tract in counteracting this torque. Two additional sets of measurements, however, are required: (1) the angles of action of the individual muscles and the angle of pull of the iliotibial tract; and (2) the length of the lever arm through which they act.

Dissections of the gluteal muscles were carried out on cadavera; the hips were in complete extension and were neutral as regards rotation. Lengths of wire were inserted along the borders and through the approximate centers of the tensor fasciae femoris, the

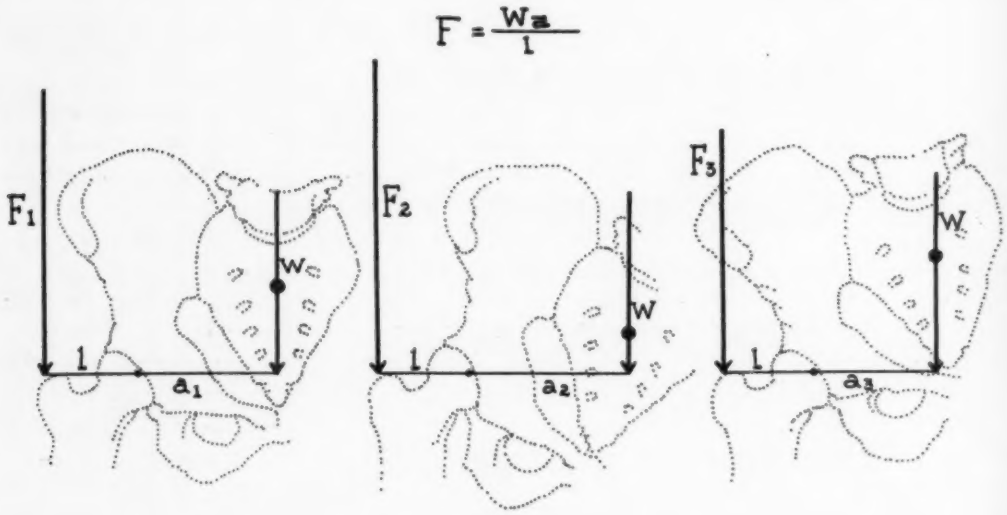


FIG. 5

Calculation of the theoretical force, *F*, with the pelvis in each of three positions.

glutaeus medius, the glutaeus minimus, and the glutaeus maximus. Roentgenograms of the specimens were taken in the anteroposterior plane at a distance of six feet. The roentgenograms obtained were comparable to those secured in the living experimental subjects. The shadows of the wires showed the direction of the muscle fibers, and the relationship of the muscles to the pelvis and to the greater trochanter.

In other cadavera the tensor fasciae femoris, the glutaeus medius, and the glutaeus minimus were carefully dissected from the bodies and soaked in a 25 per cent. solution of sodium iodide for forty-eight hours, the excess of solution being removed by gentle blotting. The muscles, both individually and in combination, were replaced in the bodies. Roentgenograms were taken by the standard technique. The muscles were found to have absorbed sufficient amounts of sodium iodide to render them partially radiopaque; and their shadows could be clearly discerned, projected onto the pelvic skeleton. From these studies it was apparent that the fibers of each muscle were sufficiently confluent, as they approached their insertions on the trochanter, to permit the drawing of a single line to indicate the direction of their pull. The line of action of the tensor fasciae latae was assumed to coincide with that of the iliotibial tract.

The angle made by each line of muscle action with the horizontal plane was measured.

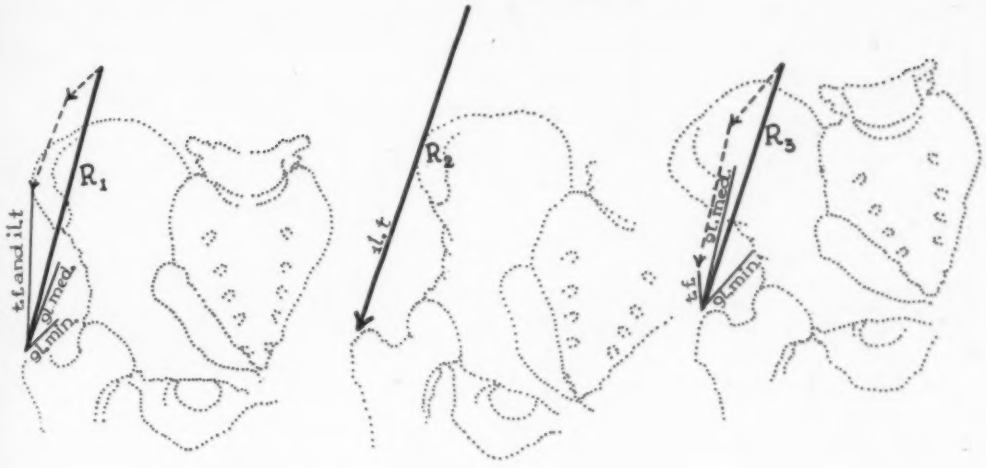


FIG. 6
Method of calculating the resultant, *R*.

The plane selected as horizontal was the one passing through the centers of rotation of both femoral heads. The angles were measured on three cadavera, and average values were calculated. These average angles were taken as determining the *direction* of the forces exerted by the muscles in the construction of a vector diagram.

The greater portion of the glutaeus maximus lay below the center of rotation of the hip joint, and only a minor portion of this muscle could conceivably act as an abductor. This finding corroborated an earlier established observation that no action potential could be obtained from the glutaeus maximus when the body was balanced on one extremity with the hip in complete extension. It was felt to be reasonably certain that the principal muscles involved in preventing pelvic rotation were the tensor fasciae femoris, the glutaeus minimus, and the glutaeus medius, together with the passive resistance of the iliotibial band.

After the direction of the pull of the muscles had been determined, it became necessary to estimate the magnitude of the force exerted by each. This was done by assuming that the force of each muscle would be approximately proportional to its mass. The tensor fasciae femoris, the glutaeus minimus, and the glutaeus medius were dissected carefully from five cadavera. These muscles were cut into small strips and desiccated to a constant dry weight. The ratios of the average muscle masses to each other were as follows:

Tensor fasciae femoris	1
Glutaeus minimus	2
Glutaeus medius	4

For ease of calculation, it was assumed that the point of application of the forces produced by the abductor muscles and the iliotibial tract was at the center of the rough area on the superolateral aspect of the greater trochanter. This was demonstrated to be accurate for the glutaeus medius and the glutaeus minimus, although the line of action of the tensor fasciae femoris fell slightly medial to it. Because of the small contribution of this muscle to the whole, it was felt that the resultant error would not be significant.

With these data, a force diagram could be constructed for the calculation of the resultant of the individual forces caused by the pull of the muscles and the tension of the fascia lata on the pelvis. Each force vector was drawn at the angle determined from roentgenographic studies, with its length in proportion to the muscle mass which it represented. Three positions were utilized: (1) with the pelvis level, (2) with the pelvis

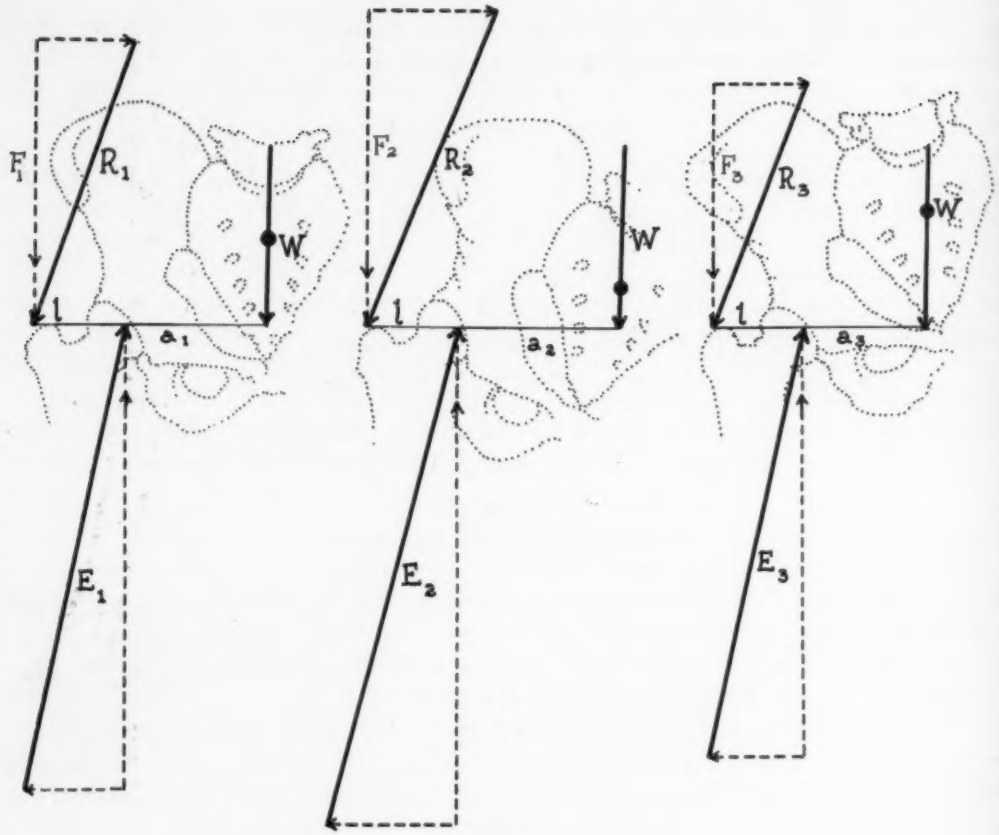


FIG. 7

Final vector diagrams for static forces.

sagging 15 degrees, and (3) with the pelvis elevated 15 degrees on the non-weight-bearing side. These were the positions employed in the experimental investigation of torque. With the pelvis level, the resistant torque about the hip was divided almost equally between the iliotibial tract and the muscles (Table I, Column D). With the pelvis sagging 15 degrees, the torque was resisted almost entirely by fascial tension alone (Table I, Column C); and with the pelvis elevated 15 degrees, the torque was resisted by the muscles alone. In these three positions, the resultant force on the pelvis was determined geometrically by the polygon method (Fig. 6).

The resultant intersected the horizontal plane at approximately the middle of the roughened area of the trochanter for the attachment of the glutaeus minimus. This point was selected as a point of application of the abducting force; the distance from this point to the center of rotation of the hip joint was the length of the lever arm. This distance was measured on the roentgenograms of the experimental subjects. With this measurement, all factors were available to complete force diagrams which included all the major static forces acting in the coronal plane about the hip. An analysis was carried out graphically.

For clarity of presentation, the three steps employed in the graphic solution are illustrated separately (Figs. 5, 6, and 7). Figure 5 indicates the method of calculating the theoretical force, *F*, acting in the vertical plane on the pelvis at the greater trochanter, which is necessary to hold the pelvis in equilibrium against the moment caused by the center of gravity being medial to the center of rotation of the hip joint. Figure 6 shows the manner of calculation, by the polygon method, of the resultant, *R*, of the forces due to the pull of the muscles and the passive tension of the iliotibial tract for the three posi-

tions of the pelvis. Figure 7 illustrates the final vector diagrams for the static forces, acting in the coronal plane. Both translatory and torsional forces are depicted.

Analysis of the vector diagrams discloses that, because of the interplay between fascial tension and active muscle contraction with the pelvis in various positions, the reacting force, *E*, remains relatively fixed in its angular relationship with the vertical, although its magnitude may vary, due to the shift in the center of gravity.

It can be said, then, that the direction of the reacting force through the head of the femur is *constant and, therefore, independent of the position of the pelvis.* The angle of this force with the vertical is from 165 to 170 degrees.

This observation is significant, for it indicates that the weight of the body normally is not borne vertically on the femur, but at an inclination which corresponds closely with the direction of the medial trabeculae of the femoral neck.

To determine the precise angle between the medial trabeculae of the femoral neck and the vertical, while the subject was bearing weight on one lower extremity, further studies were carried out. Roentgenograms were taken of a group of nine individuals while each was standing on one extremity. The angle of the medial trabeculae was measured directly on the weight-bearing side. This angle measured 169 degrees ± 0.9 degree from the vertical. In addition, the difference between the angle of the neck and the medial trabeculae was measured on thirty-eight roentgenograms, taken at random. The value of this angle (Fig. 8,*t*) varied slightly in males and females, but averaged 21.1 degrees ± 2.3 degrees (males 21.44 degrees ± 2.16 degrees and females 20.81 degrees ± 1.97 degrees). The average angle of the femoral neck (Fig. 8,*n*) was determined on 150 roentgenograms of adults, and was found to be 136 degrees ± 7.2 degrees (males 135 degrees ± 6.6 degrees and females 137 degrees ± 7.1 degrees). The average angle of inclination (Fig. 8,*i*) of the femur was quoted as 9 to 10 degrees by Martin and as 9 to 15 degrees by Walmsley. If the three angles (Fig. 8, *i*, *t*, and *n*) are added, they give the angle of the medial trabeculae with the vertical (Fig. 8,*r*). The angle of the trabeculae, so determined, lies approximately between 166 and 172 degrees. This value agrees with the direct observation (169 degrees ± 0.9 degree) on the small sample of nine individuals.

FIG. 8

Determination of angle between medial trabeculae of femoral neck and the vertical.

Attention is now invited to the close agreement between the angle of the reacting force, calculated from the vector diagrams, and the angle of the medial trabeculae of the femoral neck. Only one conclusion is possible, and that is that the resultant force, due to body weight and the pull of the abductor muscles and fascia, is transmitted to the femoral head at an angle, and that the plane of the reacting force or equilibrant in the femoral neck *coincides with that of the medial trabeculae.*

DISCUSSION AND CONCLUSIONS

The study of the forces acting in and around the hip joint explains numerous, apparently unrelated, clinical observations.

The reacting force in the head of the femur resists not merely the pressure of the superincumbent body weight, but, in addition, the force of the abductor muscles and the tension on the iliotibial tract which is necessary to hold the pelvis in equilibrium. This

latter force exceeds the weight of the body by a ratio of from 1.4:1 to 1.9:1. The minimum static pressure on the head of the femur is approximately 2.4 to 2.6 times the body weight.

Normally this force is not borne vertically, but at an angle of approximately 165 to 170 degrees from the vertical and in line with the medial trabeculae of the femoral neck. This static force remains constant in direction, irrespective of whether the pelvis is elevated or depressed on the non-weight-bearing side.

With the knowledge of the *direction* of the reacting force through the head and neck of the femur against the pelvis, the changing angle of the capital epiphysis during growth becomes partially explicable. Close inspection of roentgenograms of the upper end of the femur in individuals of various ages reveals that the epiphyseal line always lies at a right angle to the direction of the medial trabeculae of the femoral neck (Fig. 9). Since the reacting force in the femur follows these trabeculae, there is no sheer on the epiphyseal cartilage. The only force to which it is subjected normally is a compressional one. As growth occurs, with increasing length of the femoral neck and increasing angle of pull of the abductor muscles and the fascia, the epiphyseal cartilaginous plate rotates so as to lie perpendicular to the equilibrant force in the femoral neck.

The interrelationship of these forces becomes altered in cases of paralysis of the abductor muscles and in congenital dislocation of the hip. In the first instance, the loss of muscle power prevents the attainment of equilibrium with the body in a normal position. To prevent the pelvis from rotating toward the non-weight-bearing side, the individual shifts his center of gravity over the affected hip by bending to that side. The resultant forces, acting through the hip, become more nearly vertical. The equilibrant or reacting force in the femoral neck likewise shifts toward the vertical; the epiphyseal cartilaginous plate, remaining perpendicular to these forces, continues to be relatively horizontal; and coxa valga results. This is a constant finding in individuals who have had paralysis early in life, and the degree of coxa valga is in proportion to the loss of muscle power.

Coxa valga occurs in individuals suffering from congenital dislocation of the hip, for the same factors are at work. In these cases, the loss of fulcrum prevents the normal development of the abducting forces. The load is borne vertically on the femur, and the capital epiphysis reacts by remaining horizontal.

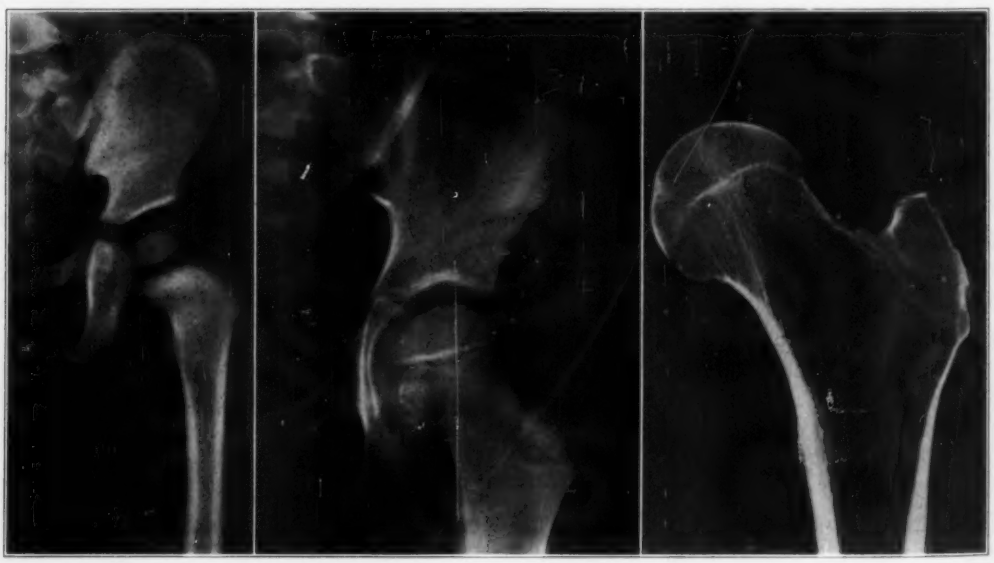


FIG. 9

Roentgenograms show the relationship of the capital epiphysis to the medial trabeculae of the femoral neck at various ages: left, at fifteen months; center, at eight years; and right, in the adult.

The so-called "antalgic" gait of the individual who has a painful disease of the hip joint is of interest. On the surface, it appears rather peculiar that a patient with a painful hip will walk by throwing himself over the painful joint, giving rise to a gait which may be compared with that of a glutaeus medius weakness. By so doing, however, the individual shifts his center of gravity over the hip, thus decreasing the required pull of the abductor muscles. This, in turn, decreases the pressure upon the femoral head from a force of 2.4 to 2.6 times the body weight to simply the superincumbent body weight. This expediency of gait, while decreasing the total load on the femoral head, results in a change in the direction of the reacting force in the femur. Instead of the body weight being borne at an angle which thrusts the head into the acetabulum, the load is carried vertically upon the femur. This alteration in direction of the forces causes changes in the femoral head, which are depicted in the roentgenograms. In malum coxae senilis, the bone changes affect predominantly the superior aspect of the femoral head, because the forces are concentrated there. In epiphysiolysis the assumption of an antalgic gait, while leading to a decrease in the total load on the femur, causes that load to be borne vertically, with the result that a sheer is applied to the epiphyseal plate, which normally is not present. This sheer will facilitate further slipping.

The importance of the abductor muscles and the iliotibial tract in altering the direction of the reacting forces in the femoral neck should be emphasized. Any surgical approach to the hip joint which injures these structures and weakens the forces exerted by them will not only modify the magnitude, but also the direction, of the reacting force through the femoral neck.

NOTE: The writer wishes to express his appreciation to John B. deC. M. Saunders, M.B., Professor of Anatomy, who willingly provided the facilities of his department; and to LeRoy C. Abbott, M.D., Professor of Orthopaedic Surgery, for his interest and encouragement.

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THE USE OF HOMOGENOUS BONE GRAFTS

A Preliminary Report on the Bone Bank *

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Since Macewen reported the first successful transplantation of bone from one person to another in 1878, the use of homogenous bone transplants has received only casual notice by orthopaedic surgeons. The reason for this has been twofold: First, the fate of homogenous bone transplants was uncertain; and, second, the preservation and availability of such tissue has been an obstacle. In the past, homografts have been used—especially in difficult cases where autogenous grafts have not been available—in such conditions as osteogenesis imperfecta, congenital pseudarthrosis, and other diseases of the bone in children.

The object of this paper is to review the literature, to report results following the use of homografts of bone in sixty-seven operations, and to report the microscopic studies of biopsies, the effects of blood type and Rh factor, and the methods used in the preservation and storing of bone.

Ghormley, in 1942, reported the use of homogenous and syngenesioplastic (syngenesious †) bone grafts in nineteen operations; eight were failures. In three, homografts were used in cases of congenital pseudarthrosis. Inclan reported the use of homogenous grafts in eight patients with six good results, one fair result, and one failure. Smith reported a series of four cases of osteogenesis imperfecta in which homogenous bone was used with excellent results. Lexer, Gill, and May have transplanted whole or half joints from homogenous sources with what would seem to be surprisingly good results.

Excellent experimental work with animals has been conducted by Macewen, Brooks and Hudson, Keith, Phemister, Murray, Axhausen, Hey Groves, Campbell, Ghormley and Stuck, Haas, Albee, Key, McGaw and Harbin, and Urist; upon their work is based our present knowledge of bone-graft surgery.

The work of some of these authors indicates that the deeper cells of cortical bone die, but that some of the cells near the periosteum, the endosteal surfaces, and the accessible Haversian canals live and grow to form new bone. The new bone develops, either from the surviving bone cells of the graft or from cells of the host, by metaplasia of connective-tissue cells. Finally, the graft is completely replaced by new bone, a process which has been aptly termed by Phemister as creeping substitution, and which Axhausen had previously called *schleichender Ersatz*. Gordon feels that grafts die and are gradually absorbed and replaced.

The studies at the New York Orthopaedic Hospital tend to support the findings of Phemister and others in respect to autogenous grafts. It is felt that a small proportion of bone cells live after transplantation of the graft. Except for the clinical results, the literature gives no information in regard to the histological fate of homografts in the human. Macewen, Ghormley, Inclan, and Smith have reported their clinical results.

Loeb stated recently that, in animals: "The bone marrow, as a rule, survived only under very favorable conditions of syngenesiotransplantation". The bone was preserved, but "it was often difficult to decide whether the cells . . . had come from the surrounding connective tissue, or whether they were actually preserved bone cells".

Armstrong stated, regarding homogenous grafts: "Bone grafts can be successfully transferred from one individual to another should the necessity arise. The donor should be healthy and free from infection, and on no account should a preliminary blood investigation

* Read before the New York Academy of Medicine, February 21, 1947.

† Although previously used as a botanical term, this word seems from its derivation to be appropriate.

be omitted. There is not sufficient evidence to show if this type of grafting is as uniformly reliable as autogenous grafting, nor do we know what relations such factors as the blood groups of the individuals concerned bear to the prospects of success."

Ghormley has made a somewhat similar statement.

Loeb [21] stated that the "evidence available at present makes very improbable a direct relationship between the four primary blood groups and the individuality differentials of host and donor". Correspondingly, there is little reason to suppose that "the particular genes determining the four blood groups determine also the fate of homoiogenous transplants . . ." Thus the four blood groups cannot be identified with the individuality differentials.

In order that homotransplants of bone may be available for use, methods of storing and preservation must be considered.

Key has recently reported successful results in the use of delayed bone grafts. Inclan stored bone in citrated blood at +5 degrees centigrade. Matthews reported the successful use of autogenous skin grafts which had been stored for twenty-one days in a household refrigerator at from +3 degrees to +6 degrees centigrade. Waterman showed that chick embryos were preserved best at +5 degrees centigrade. After refrigeration for twenty-two days, epidermis, cartilage, bone, and some skeletal muscle grew, while all other tissues died. Carrel, in 1912, reported storing tissues from an infant at +3 degrees centigrade; skin grew after forty-two days. Carrel quoted several French investigators, including Tuffier and Magitot, who preserved tissues such as bone, cartilage, and peritoneum up to two months by refrigeration, and transplanted them with good results.

Strumia and Hodge have frozen skin in plasma at from −20 degrees to −25 degrees centigrade for one to six days, with unusual success. Webster stored skin in a frozen state with good results. All grafts refrigerated for more than three weeks melted away. Keith froze bone chips in liquid air for ten minutes. Subsequent roentgenograms showed only a fair growth of bone, and microscopic examination of the tissue showed only a small amount of new-bone formation. Keith stated that this finding was a surprise.

Turner showed that the treponemata of yaws and syphilis retain their motility and virulence in rabbits after exposure to a temperature of −78 degrees centigrade for four months. Thus, until otherwise shown, all bone donors should have negative Kline or Kahn reactions.

Brooks and Hudson, and Keith showed that age was important, in that grafting of bone in young animals was 100 per cent. successful, while in old animals 40 per cent. of failures were recorded.

Loeb's extensive experiments in many species [22] indicate that grafts of the various tissues are successful in the following order: autogenous, syngenesioplastic, and homogenous. Carrel and Strumia have shown that tissues, stored or washed in saline or Ringer's solution, are less successful when transplanted. Apparently some important substance is washed from the tissues which is necessary for growth.

Some of the pertinent facts, based on experimentation or on clinical experience in relation to bone grafts, are as follows:

1. *Regeneration* in bone-grafting takes place only when the grafts are in contact with living bone. This occurs chiefly by metaplasia of connective-tissue cells. This process has been demonstrated in autogenous and homogenous bone grafts, as well as in simple fractures.

2. *Age* is important in that grafts have proved to be more successful in the young than in the aged.

3. *Sulfonamides* inhibit bone calcification, as the experiments of Benesch, Chance, and Glynn have shown.

4. *Cortical bone* is best for stability, while *cancellous bone* is preferred for osteogenesis.

5. *Blood types*, according to the author's studies, have no bearing on the success or failure of the bone graft. In a series of sixty-seven operations in which homogenous bone was used, careful records were kept of the blood types and the Rh factor of the donors and the recipients. The postoperative course was not influenced by the compatibility or non-compatibility of the blood groups. In identical operations, the morbidity of patients who had autogenous or homogenous grafts, or both, was similar.

Of seventy-three bone donors, the blood was compatible with the recipient's blood in twenty-seven, non-compatible in twenty-eight, and unknown in eighteen. These statistics would indicate that, in considering the use of homogenous bone for grafting, blood-typing studies are unnecessary.

6. *The Rh factor*, which is a property of the red blood cells, has no bearing on the results in the use of homografts.

METHODS OF USING AND STORING BONE

1. *Direct or Immediate Grafting*

Bone may be obtained from other patients upon whom operations are being performed simultaneously, or from relatives who are admitted to the hospital for this purpose; it may be transferred directly from the donor to the recipient. This method of transfer has been used in fifteen instances for homografts and in nine instances for syngenesious grafts.

2. *Delayed Grafting*

Delayed grafting, whether autogenous or homogenous, is the storing of bone in the tissues of a patient for use in secondary operations. This method has been used successfully on several occasions, but should rarely be necessary in institutions where a method of keeping a supply of bone in a bank has been instituted.

3. *Refrigeration*

This is a convenient method of preservation. For tissue to be used in the human, the temperature and duration of storage are important. The following methods of refrigeration have been used in the New York Orthopaedic Hospital:

FIG. 1-A

FIG. 1-B

Showing the equipment in which the bone is stored.

Regular Refrigeration (+2 degrees to +5 degrees centigrade): Bone may be stored at this temperature for periods up to three weeks. The bone is stored under sterile conditions in a glass, screw-top container, which is placed within a similar, larger bottle. An additional precaution to maintain sterility is to place a piece of sterile rubber sheeting (5 by 5 inches) over the top of the bottle; on this is placed a piece of gauze (4 by 5 inches), both of which are fastened securely in place by a strong rubber band (Figs. 1-A and 1-B). Such containers prevent contamination at the time of removal of the bone, evaporation, and sudden changes of temperature. This method of storage has been used by the author in thirty-seven instances.

Deep Freezing (−25 degrees centigrade): Experiments on rabbits, performed by C. Zent Garber, M.D., and the author, prove the safety of this method for the preservation and storage of rabbit bone for an indefinite period of time. The results of these experiments will be reported in another paper. The bone is stored in the type of containers just described. This method has been used in thirty instances in the human.

With both types of refrigeration, the bone is warmed to room temperature before being used. Bone which has been preserved under these conditions has the appearance of fresh bone.

Special precautions must be taken in establishing a bone bank. The bone obtained for this purpose must be free from infection or disease. A card index is kept, in which the following data are recorded for each specimen of bone: the donor's name and hospital number; the source of the bone; the Kline or Kahn reaction; a history of recent jaundice, malaria, or infections; the date of storage; and the weight of the bone. When the bone has been used, the date of use and the name of the recipient are recorded, and the card is filed.

Homogenous bone grafts have been used in sixty-seven operations (Table I), performed on fifty patients, with bone from seventy-three donors (Table II). Syngenesious grafts were used in nine children in operations for congenital pseudarthrosis, osteogenesis imperfecta, and large bone cysts. The excellent results obtained in this entire series of patients, as well as the minimum complications experienced, have been very encouraging.

It has been possible to study the areas of fusion in which homogenous bone has been added in such cases as scoliosis, where multistage operations are performed. Large, solid fused masses with abundant new-bone formation have been found. An exploration, performed on a patient who had had three operations in which bone from three different donors was used, showed a wide, thick, continuous fusion throughout the area in which the operations had been performed (Figs. 2-A and 2-B). These findings have likewise been evident in the roentgenograms in this series of cases.

Biopsy specimens were removed from twelve of these areas of fusion, in which homog-

TABLE I

TYPES OF OPERATIONS IN WHICH HOMOGENOUS BONE GRAFTS HAVE BEEN USED

Operation	Number
Fusion of the spine for:	
Scoliosis	33
Tuberculosis	2
Lumbosacral defects	8
Fusion of the ankle	3
Fusion of the wrist	2
Fusion of the hip joint	2
Onlay bone grafts	12
Grafting the cavities in osteitis fibrosis cystica	5
Total	67

TABLE II

SOURCES OF HOMOGRAFTS OF BONE

Ilium	26
Tibia	19
Ribs	2
Talar bones	12
Phalanges and metatarsals	14
Total	73

enous bone had been employed. Microscopic studies showed the bone spicules to be dead, being surrounded by connective-tissue cells with osteogenesis taking place by metaplasia of these cells, as shown in Figures 3-A, 3-B, 3-C, and 3-D. The homogenous bone, although dead and disintegrating, seems to form a trellis and to act as a stimulus for new-bone formation, and produces the necessary supply of local calcium salts for calcification of the callus. The bone is absorbed or disintegrates, and the cortical fragments are gradually replaced by living bone cells. These findings simulate those of Leriche and Policard, and of Greig.

Excess bone, removed from the ilium during such operations as arthroplasties and fusions of the hip, as well as bone from the tibia and from other sources, is placed in the bank. Prior to storage the bone is cleaned; it is cut into small pieces when used. Cortical bone is usually cut into small strips the shape of match sticks (one to two inches in length

FIG. 2-A

FIG. 2-B

Roentgenograms of spine of a patient with severe scoliosis.

Fig. 2-A: Before operation.

Fig. 2-B: After operation. Fusion was performed in three stages; homogenous bone was added at each stage. Excellent fusion was demonstrated by roentgenographic study as well as by direct exploration.

FIG. 3-A

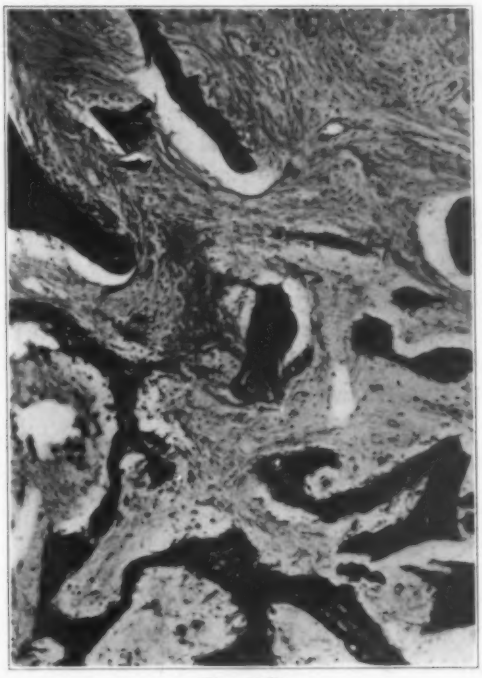

FIG. 3-B

Microscopic studies of bone removed from areas of spine fusion in which homogenous bone was used.

Fig. 3-A: Bone from the ilium was stored for fifteen days at +2 degrees centigrade; the specimen was removed twenty-one days after transplantation. Shows necrosis and erosion of bone spicule with marginal new-bone formation on one side.

Fig. 3-B: Bone from ilium, stored five days at +2 degrees centigrade, was removed from fused area after twenty-three days. Small chips of necrotic bone are present, with considerable new osteoid tissue and some new-bone formation in fibrous stroma.

FIG. 3-C

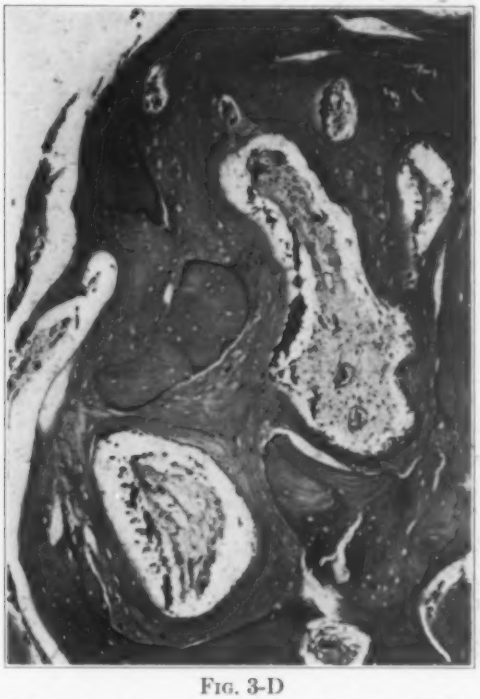

FIG. 3-D

Fig. 3-C: Bone from ilium used by direct transplantation. Specimen, removed for study forty-three days later, shows necrosis and erosion of bone chips with formation of some new marginal bone.

Fig. 3-D: Bone from ilium used by direct transplantation. Specimen, removed for study 100 days later, shows extensive new-bone formation by "creeping substitution", replacing necrotic bone.

and approximately one-sixteenth to one-eighth of an inch in width), for placement over the area to be fused. Relatives have been used as donors. As yet, it has not seemed feasible to have paid donors; and this should not be necessary, if extra bone is obtained whenever the opportunity presents itself. When special donors are necessary, a general anaesthetic is given before the bone is removed.

All suitable bone is collected and placed in the deep freezer for future use. The ilium is the best and largest source of cancellous bone; the tibia is best for cortical bone. As may be inferred from the data in Table II, all available bone has been stored.

Autogenous bone may likewise be stored for secondary operations. This procedure has been used on several occasions.

Homogenous bone may be obtained in larger quantities in the future from cases in which trauma has been the cause of death. The bone should be collected and stored immediately after death, and the necessary precautions regarding sterility should be observed.

CLINICAL RESULTS

The excellent results obtained in all but four cases lend testimony to the success of homogenous bone grafts. The use of additional bone, after the Hibbs type of spine fusion has been performed, not only diminishes the possibility of pseudarthrosis, but makes a stronger fused mass to maintain the correction. The operating time is lessened, and secondary incisions or operations for extra bone are eliminated. Examples of the clinical results, as demonstrated by roentgenograms, are shown in Figures 2-A, 2-B, 4-A, 4-B, and 4-C. In patients in whom extra donor bone has been added, there has been no

FIG. 4-A FIG. 4-B FIG. 4-C

Fig. 4-A: Shows a large bone cyst in the upper portion of the tibia, which was filled with homogenous bone chips by direct transfer from donor.

Fig. 4-B: One month after operation. Fig. 4-C: Five months after operation.

pseudarthrosis to date. A comparative study will be made of this series of cases with a previous series in which no extra bone was added.

COMPLICATIONS

Four complications which were experienced could have been expected had autogenous bone been used under similar circumstances. Homogenous grafts were used in two instances in the presence of infective arthritis; sequestration and draining sinuses resulted, which eventually healed. On the basis of our present knowledge as to the fate of homografts, as shown in the microscopic studies, this is to be expected. In the third patient, removal of bone fragments was required on two occasions, because of inability to maintain soft-tissue closure over the grafts. Microscopic study of the bone fragments removed from this patient showed the deeper areas to have definite metaplasia, with new-bone formation surrounding the dead graft. This was a syngenesious cortical graft, which was used in the repair of an ununited fracture in the presence of osteogenesis imperfecta. The ununited fracture healed, despite this complication. The fourth complication was in a patient with congenital pseudarthrosis of the tibia, which was grafted with cortical grafts from the mother. Union was accomplished, but subsequently a fracture occurred through the grafts with the development of a large callus over each graft, indicating the ability of the bone to regenerate.

SUMMARY

1. Homogenous bone may be used as a transplant under the same conditions as, or in conjunction with, autogenous bone.

2. The blood type has been shown to have no influence on the successful use of homogenous grafts of bone, nor does the Rh factor influence transplantation results.

3. Bone may be stored safely in sealed containers at from +2 degrees to +5 degrees centigrade, for periods up to three weeks. Bone may be preserved in sealed containers in the deep freezer at approximately −25 degrees centigrade for an indefinite period.

4. Microscopic studies of bone, removed from fused areas in which homogenous bone had been used, showed the grafts to be dead, but surrounded by connective tissue undergoing metaplasia and new-bone formation.

5. The success of homografts of bone has been shown by clinical results, by direct inspection of the fused area, and by roentgenographic examination.

6. Homografts of bone, available in a bone bank, will eliminate a second operation upon a normal ilium or tibia, with its possible complications; and will shorten the time of operation and of hospitalization.

7. Homogenous bone grafts were used in sixty-seven operations, with but four complications.

NOTE: The author wishes to express his appreciation to Alan DeForest Smith, M.D., for his cooperation in this work; to C. Zent Garber, M.D., whose excellent counsel and advice have been most valuable; and to William H. Von Lackum, M.D., whose forethought, enthusiasm, and inspiration caused this work to be undertaken.

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THE REPAIR OF DEFECTS OF THE RADIUS WITH FIBULAR BONE GRAFTS

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Compound fractures of the radius, with loss of bone substance and resultant nonunion, are not frequently encountered in civil life. Among the thousands of casualties treated on the Orthopaedic Service of a large Army General Hospital, however, such fractures are seen quite frequently. Over a period of eighteen months, the authors treated sixteen of these cases with fibular bone grafts.

The type of fracture under consideration usually results from a perforating wound of the forearm by a high-velocity missile. A portion of the radial shaft is more or less completely destroyed, so that no satisfactory bridge of bone remains between the major fragments to permit healing of the fracture. This report is concerned primarily with those cases in which the radial shaft was irreparably damaged, and in which the ulna either was spared entirely or sustained a fracture which had healed. Obviously, many of these cases also have associated nerve damage, as well as massive loss of muscle and skin.

Characteristic of the deformity is the prominence of the distal end of the ulna and the marked radial deviation of the hand (Fig. 2-A), resulting from shortening of the radius. Loss of active pronation and supination of the hand occurs when the defect in the radial shaft is distal to the insertion of the pronator teres. In these cases, the proximal fragment of the radius may be felt to pronate and supinate in a satisfactory manner; but the hand will not rotate, because of the loss of bony continuity of the radius. The strong rotators (biceps brachii, supinator, and pronator teres) no longer can act on the distal fragment of the radius, and the weak rotators (brachioradialis and pronator quadratus) have either been damaged by the original injury or are not strong enough to perform any appreciable rotation of the wrist and hand. In addition to abnormalities due to loss of bone, there frequently is loss of extension power in the fingers and thumb. In some of the cases, this is due to a severance of the deep branch of the radial nerve; in other cases, it may be due to actual avulsion of muscle substance.

There are both advantages and disadvantages in the use of fibular grafts. The fibular graft has the advantage of providing considerable stability to the grafted bone. Furthermore, the fibula is approximately the same size as the radius; so that ultimately, when healing is complete, the normal contour and probably the normal strength of the radius have been restored. Finally, the use of a fibular graft will avoid the infrequent, but ever imminent, complication of fracture through a tibial donor site. The primary disadvantage of the fibular graft is its relatively greater degree of dense cortical bone, as compared to tibial or iliac grafts. The osteogenic properties of the fibular graft are, therefore, not so great as those of a tibial or iliac graft. To obviate this disadvantage, it has been suggested that the drilling of multiple small holes throughout the graft might increase the vascularity and the rapidity of "take". This procedure has not been employed in any of the cases presented.

PREOPERATIVE CARE

Prior to operation, every effort must be made to eliminate all scar tissue that might break down. If the scar is narrow and the skin edges may be approximated without tension, the bone-grafting may be done at the time the scar is excised. The authors feel, however, that it is a much better plan to excise the scar first, and insert the bone graft at a second operation. A tubed pedicle graft or an abdominal-flap graft must be employed whenever

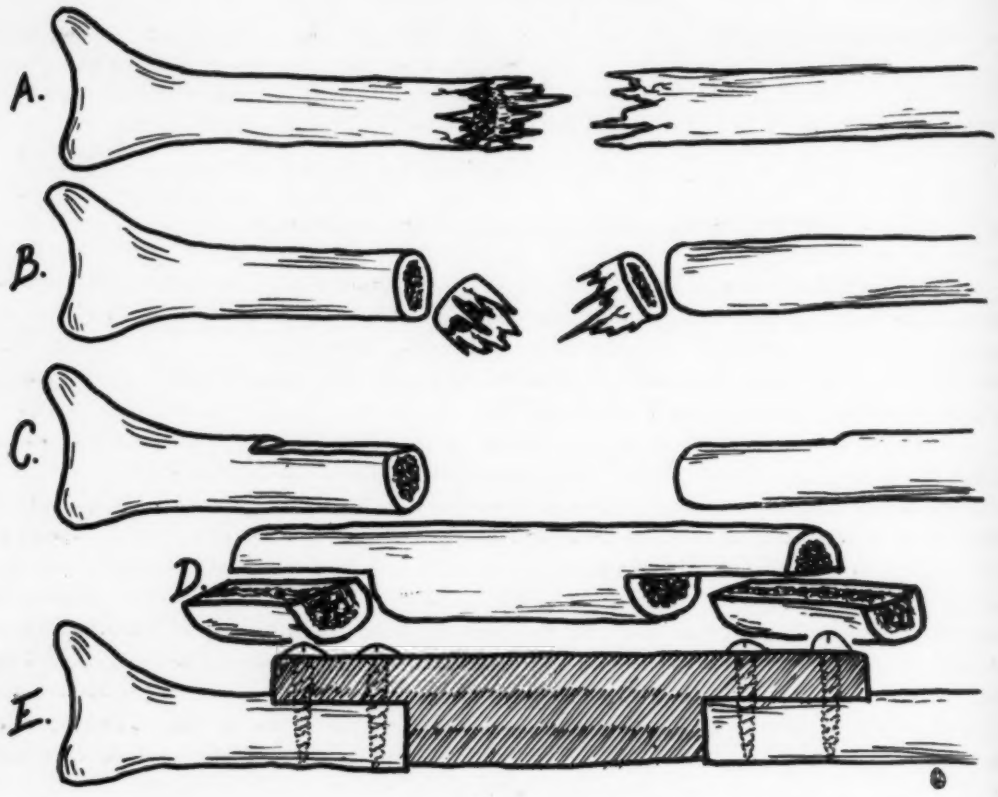

FIG. 1

Diagram of operative procedure for insertion of fibular graft.
A: Subperiosteal exposure of fragments of radius.
B: "Squaring" of bone ends, with removal of sclerotic bone.
C: Preparation of fragments to receive the graft.
D: Fibular graft, cut to fit the radial defect. The two small fragments of the graft are discarded.
E: The shaded area represents the fibular graft fixed to the radial fragments with Vitallium screws.

there is any question as to whether or not simple excision of a scar will give an adequate soft-tissue covering. It is advisable to wait at least six or eight weeks after complete healing of a pedicle graft before an operation is performed beneath it. Care must also be taken not to undermine more than 50 per cent. of the width of the pedicle graft, because of the danger of impairing circulation to the edge of the flap.

Sequestrectomy, curettage of sinuses, and removal of foreign bodies are performed as required to produce complete healing. As soon as all drainage has ceased and healing of the wound is complete, time is the greatest ally in producing a sterile field for the insertion of the bone graft. At present, the authors require a minimum of twelve weeks, if there has been no difficulty in healing. If active bone infection has been present, a longer period—up to six months—may be considered necessary. Penicillin is given in doses of 20,000 units every three hours for twenty-four hours before operation.

OPERATIVE REPAIR

The fibular graft is obtained from a normal leg, preferably that on the side opposite the fractured arm, to give the second surgical team more room in which to work. The fibular shaft is exposed subperiosteally through a lateral longitudinal incision, dissection being carried down along the posterior intermuscular septum between the peroneal and soleus muscles. Care is taken not to injure these muscles. A measured amount of fibula is then removed with a Gigli saw or osteotome. The length of the graft may be calculated before operation by adding three inches to the length of the radial defect. Proximally, as

much of the fibula as desired may be removed; this may, if necessary, include the head of the bone. It is, of course, necessary to spare the peroneal nerve as it rounds the neck of the fibula. Distally, at least three inches of the fibula must remain to maintain the stability of the ankle mortise.

By obtaining the graft in this manner, there have been few spontaneous complaints and no objective evidence of disability in the leg. In the majority of instances, only on close questioning did patients state that the leg did not possess quite the stamina that it had had before operation.

The distal end of the ulna is first excised subperiosteally through a longitudinal incision, one and one-half inches long. In a few instances, a slip of palmaris longus tendon was removed at the same time; this was used to encircle the ulna and anchor it down to the flexor carpi ulnaris. This procedure prevents the tendency for dislocation of the ulna when the arm is rotated; but, in the authors' experience, there has not been a great deal of difference symptomatically or functionally between those cases in which the ulna has been anchored to the flexor carpi ulnaris and those in which it has been left free.

The reasons for resection of the distal portion of the ulna at the time of operation justify a word of explanation. In the first patient upon whom this operation was performed, it became obvious that such resection was necessary. It was found, after exposure of the radius, that the marked deviation of the distal fragment of the radius could not be corrected, even though the fragment had been completely exposed subperiosteally. After removal of the distal end of the ulna, the distal fragment of the radius was freely movable and could be readily aligned with the proximal fragment. Subsequent to this, in most cases the operation has been begun by resection of the ulna. This facilitates the operation and also eliminates a later operation, which would probably be necessary to restore rotation to the forearm and correct the radial deviation of the hand.

Next, an adequate longitudinal incision is made over the fractured area of the radius. The exact site of the incision is determined by the location of the fracture and by the previous scarring. As a general rule, it has been found best to employ a dorsolateral incision. The superficial branch of the radial nerve is identified and protected throughout the operation. Dissection is carried down through muscle planes, usually between the extensor carpi radialis longus and the brachioradialis; and the radial fragments are exposed subperiosteally for a distance of at least one and one-half inches. Scar tissue and devitalized bone fragments are removed from the site of non-union. The ends of both radial fragments are sawed back at right angles to the shaft, until the sclerotic portion has been removed and good vascular bone is apparent (Fig. 1,*B*). This usually requires a resection of approximately one-quarter to one-half inch from each fragment.

Half the thickness of the fibular graft is then sawed from each end of the graft, leaving a central portion, which is the full thickness of the fibular shaft and measures exactly the same length as the bone defect to be bridged (Fig. 1,*D*). Care must be taken not to extend the saw cuts more than half way across the fibular shaft, in order to prevent the possibility of fracture of the graft in this area.

The radial fragments are aligned, and the decision is made as to whether the graft should be applied to the lateral or posterior surface. The corresponding surfaces of the radial fragments are then leveled down with an osteotome, so that exact contact may be obtained between the graft and each fragment (Fig. 1,*C*). If the length of the radial defect was measured while traction was being applied to the hand, the fibular graft may be mortised in snugly between the radial fragments. When the traction has been released, the end of each radial fragment will come up tightly against half of the fibular shaft, and the half-thickness ends of the fibular graft will lie as onlay grafts of approximately one and one-half inches, in close contact with the freshened area on each radial fragment (Fig. 1,*E*).

The graft is held in place by metallic fixation. The authors usually use two Vitallium

TABLE I

CLINICAL FINDINGS

Case No.	Length of Defect (*Inches*)	Length of Graft (*Inches*)	Time of Immobilization in Cast (*Weeks*)	Time of Immobilization in Brace (*Weeks*)	Operative Procedures		Results
					Skin Graft	Resection of Distal Portion of Ulna	
1	2	5	14	10	Yes	Yes	Union; good rotation
2	1¼	4	16	0	Yes	No	Union; poor rotation
3	1	4	16	14	No	No	Infection; graft sequestrated; eventual bony union by involucrum. Rotation very much restricted
4	1½	5	16	0	No	Yes	Union; good rotation
5	1	4	16	0	Yes	Yes	Union; good rotation
6	2	5	18	0	No	Yes	Union; good rotation
7	1½	4½	18	0	No	Yes	Union; good rotation
8	1¼	4	20	0	No	No	Union; poor rotation
9	5½	8½	20	20	Yes	Yes	Union; poor rotation
10	1¾	5	18	0	No	Yes	Union; good rotation
11	2	4½	20	0	Yes	Yes	Union; good rotation
12	1½	4	18	0	No	Yes	Union; good rotation
13	3	6½	14	12	No	No	Union; good rotation
14	2	5	16	—	No	No	Failure; infection developed after 8 weeks. Graft was absorbed
15	1¼	4½	16	8	Yes	Yes	Union; good rotation
16	1½	5	12	—	Yes	Yes	Partial union; still in brace

screws in each fragment; but occasionally a single screw and a loop of tantalum wire have been employed to obviate weakening the graft by a second screw hole. In some instances, the distal fragment is so osteoporotic that screws will not hold; and in these cases two double strands of No. 22 tantalum wire have been used. The wound is then closed in layers, and a long plaster cast is applied, with the elbow at a right angle and the forearm in neutral position.

POSTOPERATIVE CARE

The cast should be heavily padded to allow for postoperative swelling. In addition, suspension straps are incorporated in the cast to keep the arm elevated for a period of at least forty-eight hours after the operation. The patient is then told that he may lower his arm whenever he wishes. As a rule, the patient finds that the arm is more comfortable when it is elevated, and he seldom lowers it before the third or fourth day after the operation.

The patients are allowed to be ambulatory as soon as the leg wound has healed, which usually is on the tenth day. Frequently an elastic bandage is employed to prevent swelling in the leg. No definite instructions are given about walking, other than reassurance; and the patients are permitted to be up and around as soon as they feel comfortably able to do so. At first they are somewhat hesitant to walk on the leg, and they may use a crutch or cane. Within a period of two or three weeks, they are ambulatory without support, but they may still limp slightly. Within a month after removal of the graft, nearly all complaints referable to the donor site have disappeared, and the patients are ambulatory without limp.

The bulky arm cast is removed, the wound inspected, and the sutures removed any time after the eighteenth day after operation. By this time the cast has become somewhat loose, and it must be replaced by a snug-fitting cast with only a minimum amount of padding. The hand portion of the cast is trimmed back sufficiently to permit full motion in the fingers and thumb. These casts are usually changed at six-week intervals, and the progress of bone healing is checked by means of roentgenograms. A cast is usually worn for at least four months, and then a brace of metal and leather may be applied to give further support for another two or three months. The graft must be protected against fracture until roentgenograms show that it has been well incorporated into the radius.

Physical therapy may be instituted to mobilize the elbow and wrist as soon as the arm has been removed permanently from the plaster cast. Forceful active or passive rotation of the forearm is not permitted, however, until roentgenograms show complete healing.

FIG. 2-A FIG. 2-B

Fig. 2-A: Case 4. Preoperative condition of forearm, showing radial deviation of hand and prominence of ulnar styloid.

Fig. 2-B: Postoperative condition of forearm, showing correction of deformity and restoration of normal contour of forearm.

COMPLICATIONS

One complication that has constantly to be guarded against is that of infection. In the present series, this occurred in two cases; in one case the purulent drainage had its onset twelve weeks after the operation, and in the other case it occurred eight weeks after operation. In addition to the precautions taken in regard to the skin of the forearm and the time interval between cessation of drainage and insertion of the bone graft, penicillin is administered for one day before operation and both penicillin and sulfadiazine are given for at least six or seven days after operation, or until the patient has remained afebrile for at least three days and there is no longer any undue swelling in the hand or other evidence of infection in the arm. Sulfadiazine may aid in controlling some of the organisms which are not especially sensitive to penicillin; but the administration of sulfadiazine is not considered absolutely essential if penicillin can be given.

Another complication to be considered is fracture of the bone graft. Although this did not occur in this series of cases of fracture of the radius, two instances of fracture were seen in which a similar type of graft was employed on a defect of the ulna. In both of these cases, the trauma was minimum. In one case, the arm was still immobilized in a plaster cast; in the other case, all immobilization had been removed two months before the patient's transfer to our care. Both of these fractures occurred at the junction of the graft and the ulnar fragment. This indicates that very accurate contact between the graft and the fracture fragments should be obtained, so that healing will occur, not only between the onlay portion of the graft and the fragments, but also between the fragments and the portion of the graft that is mortised in between the ends of the bone.

Fibular grafts are probably revascularized more slowly than similar grafts removed from the tibia or ilium. To avoid the possibility of fracture of the graft, immobilization in plaster casts should be maintained for at least fourteen to eighteen weeks, followed by

FIG. 2-C

FIG. 2-D

FIG. 2-E

Fig. 2-C: Anteroposterior and lateral roentgenograms of forearm, six months after injury. Note the angulation of the distal fragment of the radius.

Fig. 2-D: Anteroposterior and lateral roentgenograms of forearm, three months after insertion of fibular graft and resection of the distal end of the ulna. The two metallic fragments in the soft tissues were not encountered at time of operation and were, therefore, not removed.

Fig. 2-E: Anteroposterior and lateral roentgenograms of leg, three months after removal of fibular graft. Note the minimum regeneration of the fibula. Patient had no complaints referable to leg.

FIG. 3-A

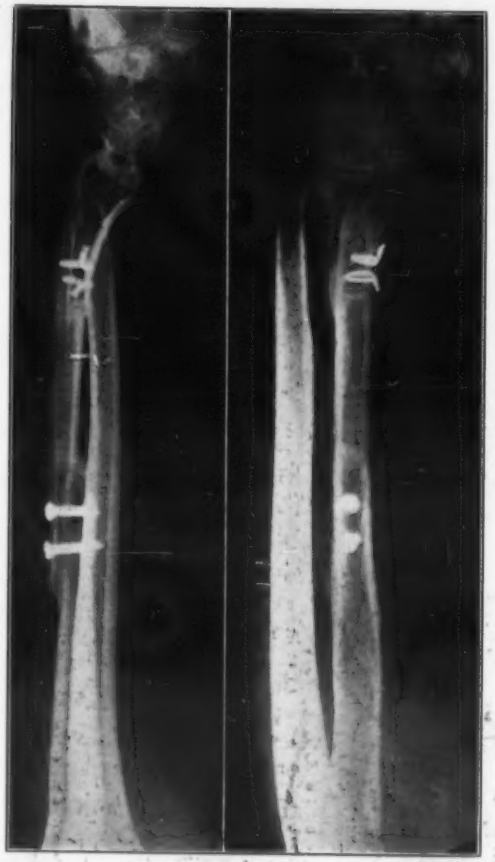

FIG. 3-B

FIG. 4

Fig. 3-A: Case 11. Lateral and anteroposterior roentgenograms of forearm, five months after injury. Note the relative increase in length of the ulna.

Fig. 3-B: Lateral and anteroposterior roentgenograms of forearm, four and one-half months after insertion of fibular graft. Because of marked osteoporosis of distal fragment of radius, it was necessary to fix the graft to this fragment with two loops of tantalum wire.

Fig. 4: Case 1. Lateral and anteroposterior roentgenograms of forearm, eleven months after insertion of fibular graft. Patient has excellent range of motion in wrist and good rotation in forearm. The fibular graft has been well incorporated and the normal radial contour has been restored.

another period of from eight to twelve weeks of protection in a metal and leather arm brace.

DISCUSSION OF CASES

Findings in the sixteen cases in this series are summarized in Table I. There was one failure, resulting from infection, which first became apparent eight weeks after the operation (Case 14).

The radial defects have ranged in length from one inch to five and one-half inches. These represent the defects in the radius subsequent to the operative "squaring" of the bone ends. The actual loss of bone substance was usually from one-quarter to one-half inch less than the figures given.

In general, the fibular grafts were three inches longer than the radial defects. This allowed for one and one-half inches of onlay graft on each radial fragment. In two cases, the defect was so close to the wrist joint that the distal onlay portion of the graft had to be shortened to one inch.

Immobilization of the entire arm in a plaster cast was continued for from fourteen to twenty weeks. A long brace, with a hinged portion at the elbow and a palmar bar, was applied in four cases. Although this brace was used only for patients whose roentgenograms showed some delay in complete incorporation of the graft into the radius, it is probably advisable to apply such a brace to all patients after a four-month period of immobilization in a cast. The brace permits mobilization of the elbow joint, but it prevents rotation of the forearm and protects the forearm until complete revascularization of the graft has occurred. In Case 9, the patient wore such a brace for twenty weeks after the cast had been removed. This patient had the largest defect and the longest graft.

In seven of the sixteen patients (44 per cent.), scars of the forearm were replaced by abdominal flaps or tubed pedicle grafts. All of the other patients required simple excision of scars. Most of the scars were excised as a separate operation, prior to insertion of the fibular graft.

The distal end of the ulna was not resected in five of the sixteen cases. In three of these five cases, rotation of the forearm has subsequently been greatly restricted. In one of these patients (Case 3) infection occurred, and rotation in this case was limited to a total range of 20 degrees. Rotation in the other two cases was limited to a total range of 30 degrees. In the two more recent cases in which the ulna has not been resected (Cases 13 and 14), healed fractures of the ulna were present with sufficient shortening so that the relative length of the radius and ulna could be restored without further resection of the ulna.

All of the patients in whom the distal end of the ulna has been resected have regained a satisfactory range of rotation in the forearm (more than 100 degrees), except one (Case 9). This patient is restricted to an active range of 20 degrees and a passive range of 50 degrees; he had the largest defect, and has apparently lost the action of the strong rotator muscles. It was necessary to use prolonged immobilization in this case.

OSTEOSYNTHESIS OF INTERTROCHANTERIC AND PERTROCHANTERIC FRACTURES OF THE FEMUR

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In distinction from subcapital and transcervical fractures, which usually are intracapsular, the intertrochanteric and pertrochanteric fractures of the femur, which run extracapsularly, show a favorable healing tendency and, in this respect, may be regarded as "benign" fractures. In these fractures, with relatively few exceptions, reposition entails no great difficulties. The method of treatment usually adopted is wire traction through the tuberosity of the tibia or the lower end of the femur.

The disadvantages and hazards of traction treatment are particularly evident in these fractures, for the following reasons:

1. The ages of the patients as a rule are high, averaging over seventy years. According to Spotoft, they are higher than for fractures of the neck of the femur.

2. Except in certain fractures, where there is no displacement of the fragments, the wire traction should be continued for ten, twelve, or fourteen weeks. Coxa vara may occur at a very late stage—after the lapse of several months—even if the patient had not been allowed to put his weight on the fractured extremity. [5] The lengthy immobilization is very trying for these aged patients and, in a considerable number of cases, their condition is such that the traction treatment either cannot be applied consistently or must be discontinued prematurely.

3. The amount of traction should be about one-tenth of the body weight, and careful supervision with frequent roentgenograms is required. Healing in a coxa vara position is by no means infrequent. The limb has a strong tendency toward outward rotation. Even if healing in this faulty position does not affect the hip joint greatly, it is unfavorable for the function of the knee joint.

4. Traction treatment also has local drawbacks. In many cases a traction wire which has been retained a long time becomes a focus of infection, which, however, usually heals rapidly after the wire has been removed. If the wire has been applied supracondylarly through the femur, however, the infection frequently leads to cicatrization in the quadriceps and the formation of adhesions around and in the suprapatellar recess, with permanent restriction of the mobility of the joint. If the wire slips, the risk of pyarthrosis in the knee joint is imminent. Even if the wire is placed below the knee joint, through the tuberosity of the tibia, traction treatment for some length of time may entail protracted symptoms in the knee joint. For these fractures, the patient usually must stay in the hospital about four or five months. For certain fractures without displacement, the hospital stay is somewhat shorter; but for various fractures with a markedly faulty position, as well as in cases where complications supervene, it is considerably longer.

The intertrochanteric and pertrochanteric fractures of the femur produce a higher mortality rate than do fractures of the neck. Key stated that, at St. Louis City Hospital, the mortality rate in a series of 214 fractures in the trochanteric region was 38 per cent., whereas the mortality for 166 intracapsular fractures of the neck at the same Hospital was 25.9 per cent. Both groups were treated in the same way. Siler and Caldwell found a mortality rate of 30.1 per cent. in 103 cases. In Speed's 118 cases, the mortality was 18.6 per cent. Wadstein, in thirty-one cases, had a mortality rate of 32 per cent. The author can unreservedly endorse Lippmann's statement that "the death rate is considerably higher than the severity of the original injury would indicate . . ."

*Service of Docent Ivar Palmer, M.D.

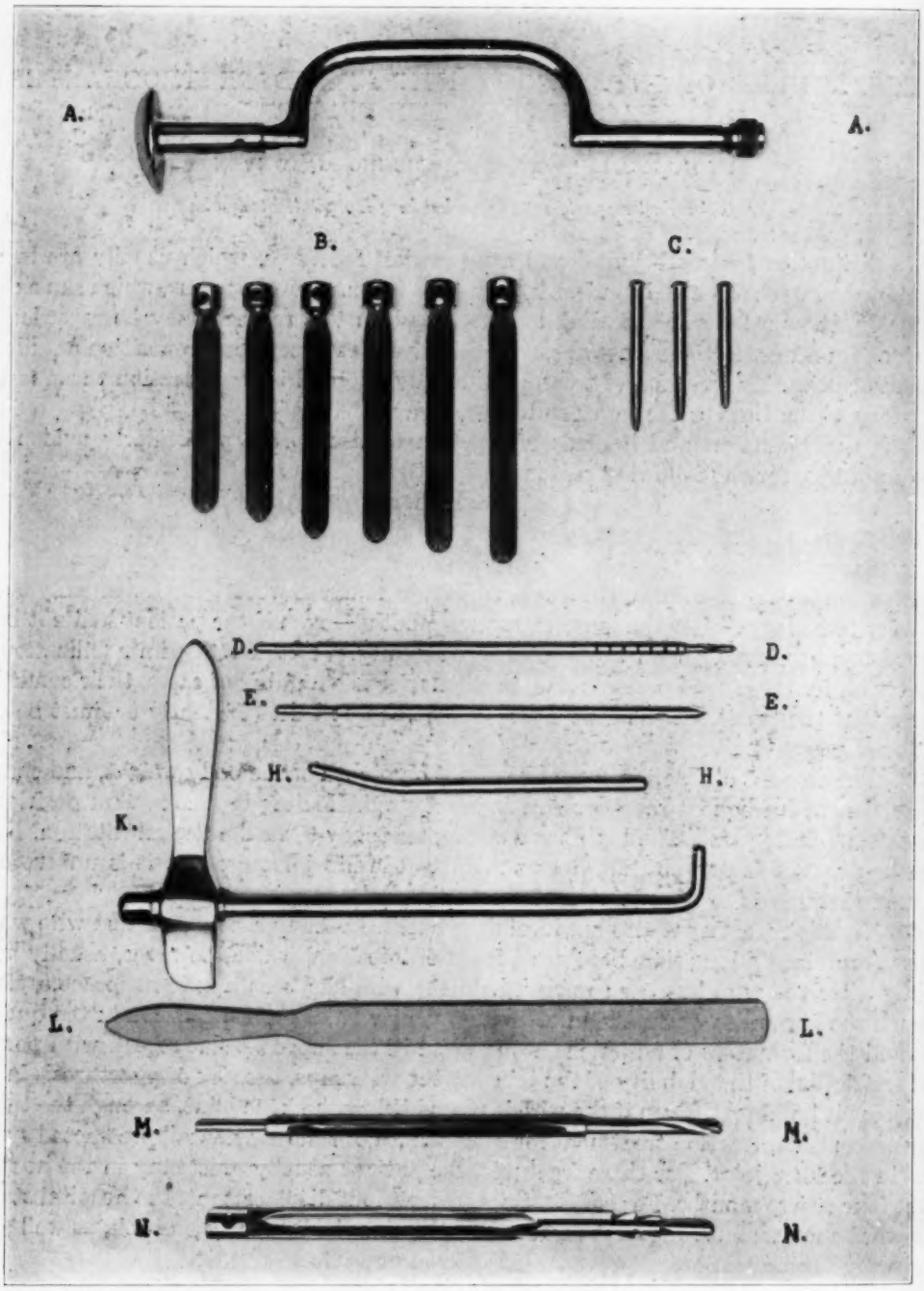

FIG. 1

A: Brace for screws and drill bit.
B: Three-flanged nails with transverse channel, 6 millimeters in diameter, through the head, which can be rotated.
C: Screws 6 millimeters in diameter, threaded 2 centimeters from the tip.
D: Drill with guide sleeve, 6 millimeters in diameter, and with 4-millimeter drill bit at the tip. Graduated with centimeter scale, reckoned from the tip.
E: Drill 6 millimeters in diameter.
H: Pin, 6 millimeters in diameter, for adjustment of transverse channel through nail head.
K: Instrument for extraction of nails.
L: Hammering bar.
M: Preparatory drill for von Bahr's chisel, which cuts in three planes.
N: von Bahr's chisel.

FIG. 2-A
Fracture before operation.

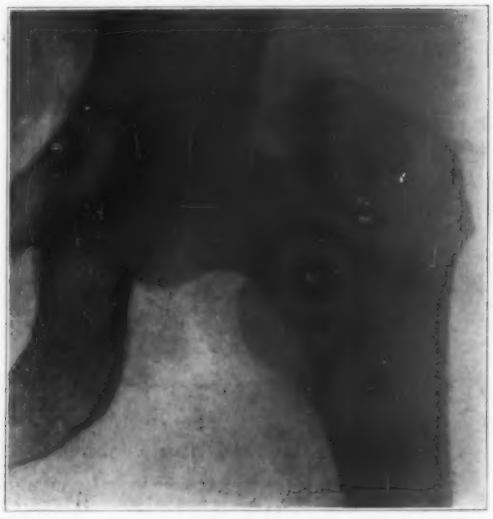

FIG. 3-A
Fracture before operation.

FIG. 2-B
After osteosynthesis.

FIG. 3-B
After osteosynthesis.

In order to avoid the disadvantages of traction treatment and to enable the injured patients to move more freely, osteosynthesis of these fractures has been recommended by Sven Johansson, Brittain, Moore, Spotoft, Watson-Jones, and others. In Sweden, the procedures most commonly adopted for osteosynthesis of fractures of the neck of the femur are Sven Johansson's method with Smith-Petersen's three-flanged nail and Nyström's method with multiple nails. Each of these procedures, however, is suitable only in exceptional cases of these fractures.

At the Sabbatsberg Hospital, Smith-Petersen's three-flanged nail with a transverse

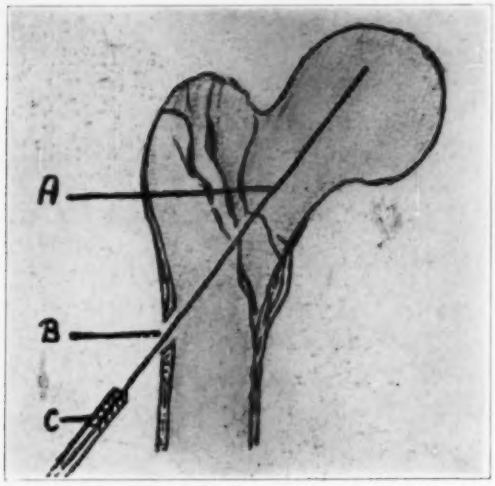

FIG. 4

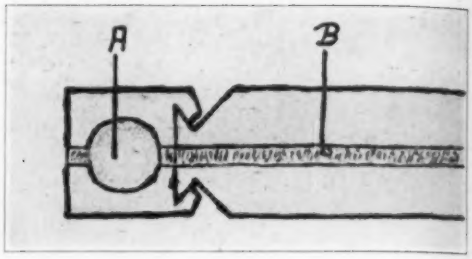

FIG. 5

Fig. 4: *A:* Wire guide has been introduced in oblique position.
B: Groove has been drilled around wire guide in outer cortex of femur.
C: Thick drill with central groove for guide.
Fig. 5: Cross section through nail with transverse channel and head which can be rotated.
A: Transverse channel. *B:* Groove for guide.

screw through the head of the nail has been used since January 1945 in the osteosynthesis of intertrochanteric and pertrochanteric fractures of the femur. In order to facilitate the introduction of this screw and to obtain a diametrical support for the screw in the femur, a nail with a head which can be rotated has been employed. By the combination of a three-flanged nail and a transverse screw, the marked tendency toward coxa vara at the site of fracture and the possibility of outward rotation of the distal fragments are obviated. When the bone around the wire guide is prepared before nailing, either with the aid of a large-sized drill provided with a central groove (Fig. 4,*C*) or, better, with a chisel of von Bahr's design which cuts in three planes (Fig. 1,*M* and *N*), the risk of the bone being cracked during the driving in of the nail—which would result in inadequate fixation—is diminished.

Figure 1 shows the set of instruments, and in Figures 2-A, 2-B, 3-A, and 3-B are presented roentgenograms of two patients, before and after osteosynthesis.

The method of osteosynthesis in these cases differs considerably from the technique employed in osteosynthesis of subcapital and transcervical fractures of the femur. The wire guide is inserted in a similar way, but somewhat lower on the femur, in order to obtain a sufficiently oblique position of the nail. The guide thus forms a smaller angle with the femur than in ordinary nailing of the neck. The cortex of the femur increases in thickness distally and becomes increasingly solid. If one attempted to drive in the nail directly, the bone would be splintered, so that cracks would reach up to the trochanter and the site of fracture. The fixation would thus be defective. In order to facilitate the introduction of the nail without cracking the bone, a channel in the outer cortex of the femur around the guide is made with a drill, eleven millimeters in thickness, cannulated for the guide (Fig. 4,*C*) and adapted to Sven Johansson's brace (Fig. 1,*A*). The nail, when driven in, is thus fixed securely without splintering the bone. With a chisel of von Bahr's design, which cuts in three planes, the same purpose can be attained in a neater way. With a smaller drill (Fig. 1,*M*), also cannulated, a channel corresponding to the core of the nail is prepared around the guide. With von Bahr's chisel, a stellar figure is cut in the cortex around the guide. The three-flanged nail fits this figure and can thus be inserted without damaging the cortex.

When driving in the nail, care must be taken that the transverse channel through the head of the nail is in such a position that the screw, when inserted, will pass, as far as possible, diametrically through the femur, with support both in its inner and outer cortices. A minor deviation (10 to 20 degrees) in the direction of the transverse channel may suffice to prevent the screw from having a diametrical support; it will then pass

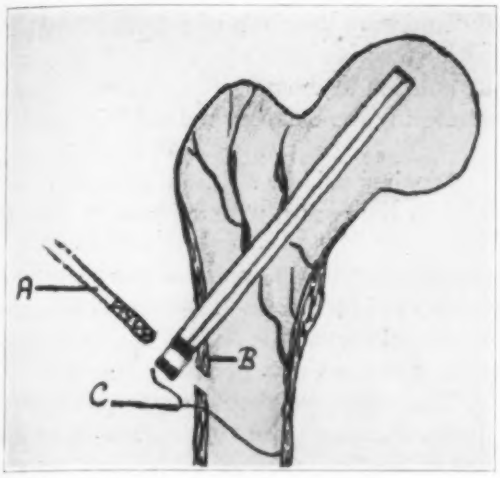

FIG. 6

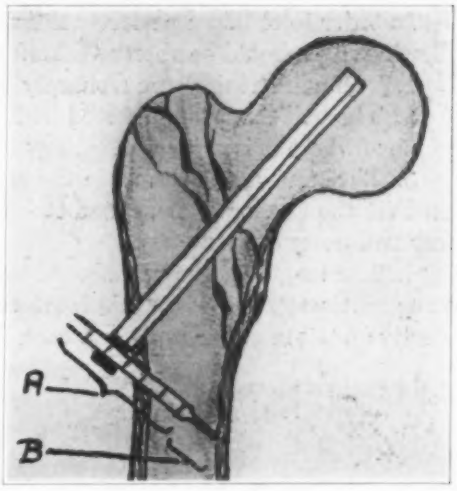

FIG. 7

Fig. 6: *A:* Drill has been introduced into transverse channel through nail head, for drilling outer cortex of femur before insertion of screw.
B: Bridge of bone between nail and screw.
C: Length of screw.
Fig. 7: Drilling of inner cortex of femur.
A: Guide sleeve with centimeter scale from the tip.
B: Drill, 4 millimeters in diameter, for drilling inner cortex of femur.
Fig. 8: Screw has been inserted and osteosynthesis is complete.

FIG. 8

tangentially through the femur, anteriorly or posteriorly, and the fixation will consequently be defective. In order to improve this detail in the technique, the author has designed a nail with a head which can be rotated (Figs. 1,*B* and 5), so that the transverse channel in the head of the nail can be adjusted after it has been driven in, with a pin six millimeters in diameter (Fig. 1, *H*), in the optimum position for the insertion of the screw. This construction involves some weakening of the osteosynthesis material at the place exposed to the severest strain, but the author has not found any disadvantages.

When the nail has been inserted in the position shown in Figure 6, the outer and inner cortices of the femur are drilled in order to facilitate the introduction of the screw into the femur. The transverse channel in the head of the nail, and the screw, are six millimeters in diameter. With a drill of that diameter (Figs. 1,*E* and 6,*A*) introduced into the channel, the outer cortex of the femur is drilled, a narrow bridge of bone being formed between the place where the nail is driven in and the drilled channel. Then the inner cortex of the femur is drilled with an instrument (Fig. 1,*D*) which has a guide sleeve of the same diameter as the channel in the head of the nail, namely, six millimeters, but a drill bit four millimeters in diameter at its tip (Fig. 7). The pointed end of the screw, the threaded part of which is two centimeters in length, will thus exactly hit the drilled spot in the inner cortex of the femur. The instrument is graduated from its tip in centimeters, so that the length of the screw can be read directly. The screw is adapted for, and is introduced with, Sven Johansson's brace. Should the nail have to be extracted, an instrument (Fig. 1,*K*), the bent part of which fits the transverse channel, is employed. Figure 1,*L* shows a suitable hammering bar.

In order to obtain a perfectly satisfactory fixation in this form of osteosynthesis, the following rules should be observed carefully:

1. The nail should have a sharply oblique position in the neck.

2. The nail should be inserted without splintering the bone around the wire guide at the place where it is driven in.

3. The transverse channel in the head of the nail should be adjusted in such a direction that the screw will pass diametrically through the femur, with support in both the inner and outer cortices.

4. The length of the nail should be measured exactly. The point of the nail should lie one centimeter below the joint surface of the head of the femur. If the nail is too short, defective fixation of the head and neck fragments will result; if it is too long, there is the risk that the nail may penetrate into the joint.

FIG. 9

Type of fracture not suitable for this method of osteosynthesis.

The majority (about 80 per cent.) of the intertrochanteric and pertrochanteric fractures of the femur are suited for treatment by this method. Pertrochanteric fractures approaching the subtrochanteric type, as well as fractures with cracks running down into the shaft fragment, on the other hand, are not suitable for such treatment (Fig. 9). The essential condition for osteosynthesis is a satisfactory position of the fracture during manipulated reposition on a fracture table. If, in exceptional cases, a satisfactory fracture position cannot be obtained, the operation should not be performed. Cases not suited for this procedure have been treated with balanced traction.

Advanced age and general infirmity are not contra-indications, provided the patient is not in such a bad condition that other methods of treatment are likewise contra-indicated. Some of the patients were operated upon under low-spinal anaesthesia. In the majority, however, intravenous narcosis was produced with narcotal in combination with nitrous oxide; this method seems preferable.

During the period from January 1945 to April 1946, thirty patients, whose ages averaged seventy-seven years, were operated upon at Sabbatsberg Hospital. The mortality rate during their stay in the Hospital was 10 per cent. Two of the patients who died were eighty-five years of age; the third was eighty-three. They were very infirm and died of generalized arteriosclerosis with senile marasmus and terminal bronchopneumonia.

Dissection in two of these cases showed the fixation to be satisfactory. In the third case it was not satisfactory. The reason was that, while the nail was being driven in, the bone had been cracked as far as the region of the fracture. The operator had not followed the preliminary procedure described here. Redisplacement of the fragments after the operation occurred in one of the other cases. In this case, which was one of the first, the operator had not managed to get the screw through the femur; it skirted the rear part of the bone.

These two cases illustrate the importance of an exact technique. In the other case, the position of the fracture had remained unchanged despite mobile treatment.

After the operation, the patient was allowed to lie freely in bed, as after an operation for fracture of the neck of the femur, and at once to begin to move the extremity. When he

was able to lift the limb from the bed, and when the general condition permitted, he was allowed to sit in a chair. After about four or five weeks, he began to stand on the limb. The hospital stay averaged fifty-five days. Upon discharge from the Hospital, the patients were able to walk, with the support of a stick, and the mobility of their hip joints and knee joints was satisfactory.

SUMMARY

Intertrochanteric and pertrochanteric fractures of the femur, with respect to healing, may be regarded as benign fractures. The patients most apt to incur these fractures are the aged, and the mortality rate is high. Methods of treatment that require a lengthy confinement in bed should be avoided.

The operative procedure reported, which was used in thirty cases at the Sabbatsberg Hospital, is not more serious than that employed in cases of fracture of the neck of the femur. If performed correctly in suitable cases, it gives satisfactory internal fixation and permits early mobilization. The injured patient is easily cared for, so that the work of the nursing staff is lightened; the patient more rapidly recovers mobility and capacity for walking; and the hospital stay is shortened.

The mortality in this series of thirty cases was 10 per cent. The number of cases is too small to enable one to judge whether or not this operative procedure has produced a real reduction in mortality.

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OPERATIVE TREATMENT OF PARALYTIC GENU RECURVATUM

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Genu recurvatum resulting from infantile paralysis is unsightly, and sometimes produces a severely disabling deformity. It is usually associated with such an extensive disability of the entire extremity that other factors, in addition to the back-knee, necessitate the wearing of a brace; and alleviation of the disability at the knee alone does not materially benefit the patient. If stabilization of the knee will enable the patient to walk without a brace, or if it appears likely that a mild deformity will progress, correction by operation is indicated.

Genu recurvatum may be caused by infantile paralysis in cases in which an excessive and continual strain is exerted upon the posterior capsular ligaments at the knee, causing them to stretch. Paralysis of the hamstrings or gastrocnemius, or especially paralysis of both, is a contributing factor. The deformity may also be a result of leverage force, exerted upon the back of the knee by a short Achilles tendon in the presence of paralyzed hamstrings. The repeated backward thrusts of the hyperextended knee stretch the collateral and cruciate ligaments, allowing still more hyperextension. Eventually, structural deformity of the condyles of the tibia, consisting of a downward inclination of the anterior portion of the articular surface, furthers the abnormality and adds to the difficulty of correcting it. Correction of the condition before bone deformity occurs is, of course, desirable.

Correction of genu recurvatum requires, first of all, elimination of as many of the contributing factors as possible. Operations upon the knee itself are directed toward strengthening or reinforcing the posterior ligamentous structures, the construction of a bone block anteriorly, or elevation of the anterior articular surface of the tibia. These supports are passive in function. The author knows of no way to provide active resistance to hyperextension.

In the absence of bone deformity, the writer has tried to construct check ligaments, because this method appears rational and is conservative. Two operations have been devised,—one to enhance the function of the collateral ligaments in resisting hyperextension, and the other to construct a check ligament behind the knee. Each has given good results and is indicated in certain conditions.

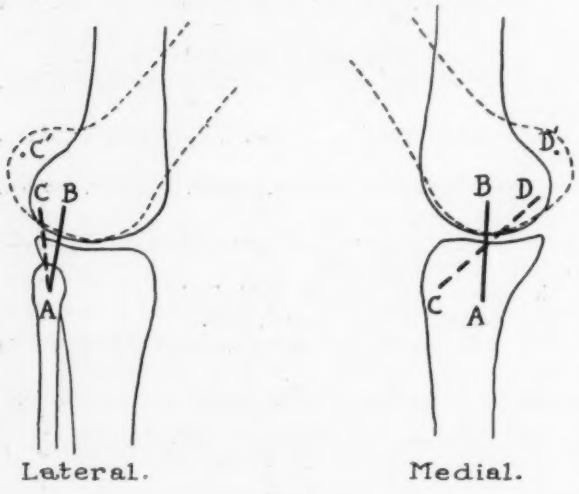

FIG. 1

The fibular and tibial collateral ligaments are represented by the heavy lines AB. The interrupted lines AC and CD represent newly constructed ligaments with the femoral attachments shifted posteriorly. C' and D' are the attachments of C and D, respectively, with the knee in recurvatum, which would be impossible if the band held. Reconstruction of the collateral ligaments according to this plan corrects lateral instability as well as genu recurvatum.

If there is no bone abnormality, hyperextension of the knee is prevented by competent anterior cruciate and collateral ligaments; and it would appear to be rational that genu recurvatum could be corrected by reconstruction of the collateral ligaments in a position which would augment their resistance to hyperextension. This has been accomplished by reattaching the femoral insertions of reconstructed collateral ligaments at a point more posterior on the femoral condyles. A description of such an

FIG. 4

FIG. 5

FIG. 2

FIG. 3

Figs. 2 and 3: Show the method of utilizing the tendons of the gracilis and semitendinosus for tenodesis, implanting them into the posterior aspect of the internal condyle of the femur to reconstruct a tibial collateral ligament which enhances resistance to hyperextension.

Figs. 4 and 5: Show the method of reconstructing the fibular collateral ligament, utilizing the biceps tendon and a tube of fascia lata. This will also resist hyperextension.

operation was published by the author in 1924, and this is believed to have been the first operation designed to correct genu recurvatum by the construction of ligamentous or fascial resistance to hyperextension. In brief, this consisted of a modification of the Edwards operation for reconstruction of the collateral ligaments in which the biceps tendon, or a portion of it, is implanted into the posterior aspect of the lateral condyle of the femur, and is reinforced by turning down a strip of fascia lata to form an insertion into the head of the fibula. The tendons of the semitendinosus and gracilis are implanted into the posterior aspect of the medial condyle of the femur to reinforce the tibial collateral ligament. These structures on both sides of the knee, extending from below upward and backward, check not only lateral mobility, but also a backward thrust of the femur on the tibia. The basic principle of the operation is shown in Figure 1, and the important operative steps are outlined in Figures 2, 3, 4, and 5. Other methods to construct check ligaments have been described by Colonna in 1930, Gill in 1931, and Carrell in 1937.

Construction of an anterior bone block was described by Campbell in 1918. Mayer adopted this in principle, but modified the technique. Brett, in 1935, reported good results by elevating the tibial plateau anteriorly in cases in which bone deformity was the cause of genu recurvatum; Campbell accomplished this by a subcondylar osteotomy, and maintained elevation by inserting cancellous bone into the gap. Irwin, in 1942, described a method of subcondylar osteotomy of the tibia whereby the tibial plateau was lowered posteriorly. Sutherland and Rowe modified Brett's operation by inserting a metal wedge anteriorly, only 0.5 centimeter distal to the anterior articular surface of the tibia. They stated that Brett's operation could be done prior to closure of the epiphysis, although Brett, in a second paper, specified lateral stability and adult bone growth as prerequisites. Other methods of treatment have been arthrodesis of the knee and supracondylar osteotomy of the femur. Arthrodesis results in the disability of a stiff knee, and is contraindicated in bilateral cases. Osteotomy of the femur does not appear to be rational.

It is not intended in this paper to pass judgment upon the efficacy of a bone block at the knee. It would seem from a purely speculative consideration, however, that an anterior bone block would have no effect upon the lateral instability which so frequently accompanies genu recurvatum. Mayer had this experience, and found it necessary to construct additional blocks of bone at the sides of the knee in an attempt to correct lateral instability, which persisted after the construction of an anterior bone block. There is also the possibility of a subsequent traumatic arthritis, since a bone block cannot conform so accurately to the articular surface of the femur as does the olecranon surface to the humerus. An osteoplastic method of restoring the normal plane of inclination of the tibial plateau is indicated when bone deformity is a major factor in genu recurvatum. Brett's operation is limited by his prerequisites of lateral stability and adult bone growth, and it would appear that subcondylar osteotomy of the tibia would not correct lateral instability.

Reconstruction of the collateral ligaments by implanting the attachment at a position more posterior on the femoral condyles has been done in a small number of cases. They are not numerous, because at least fair strength in the quadriceps is necessary to lock the knee, and there must be sufficient strength in other muscles of the extremity and sufficient stability at the hip and foot to enable the patient to walk without a brace. Good stability has been maintained in five of seven operations performed according to this method, with recurrence of deformity to not more than a mild degree, not necessitating the wearing of a brace. The first patient operated upon and reported in 1924, with a bilateral deformity, was lost from observation two years after operation, but reappeared unexpectedly fifteen years later while passing through Cleveland on a "hitchhike" trip from the West Coast. During this trip, he had frequently walked ten miles a day. There was excellent stability of both knees, and only slight hyperextension. In another patient, also a bilateral case, and in a third, a unilateral case, no recurrence of disabling genu recurvatum is known to have occurred ten years after the operations. Failures occurred in two cases; these were

attributed to osteoporosis of the femoral condyles, which prevented a secure anchorage of the reconstructed ligaments by the method which was then used. In fact, this was so obvious during the course of an operation in 1931 that the operation was not completed.

Another method was, therefore, desirable to obtain a firm resistant implantation in bone, even in the presence of osteoporosis. As a result of assurance from previously successful cases that a fascial or tendinous support would maintain correction of genu recurvatum, an operation was devised to pass the transplanted tendon or fascia completely through the tibia and femur to provide a direct support for the posterior aspect of the knee (Fig. 6). The approach used for the capsuloplasty of Philip Wilson provides an adequate exposure; and the patient mentioned previously, upon whom operation had been

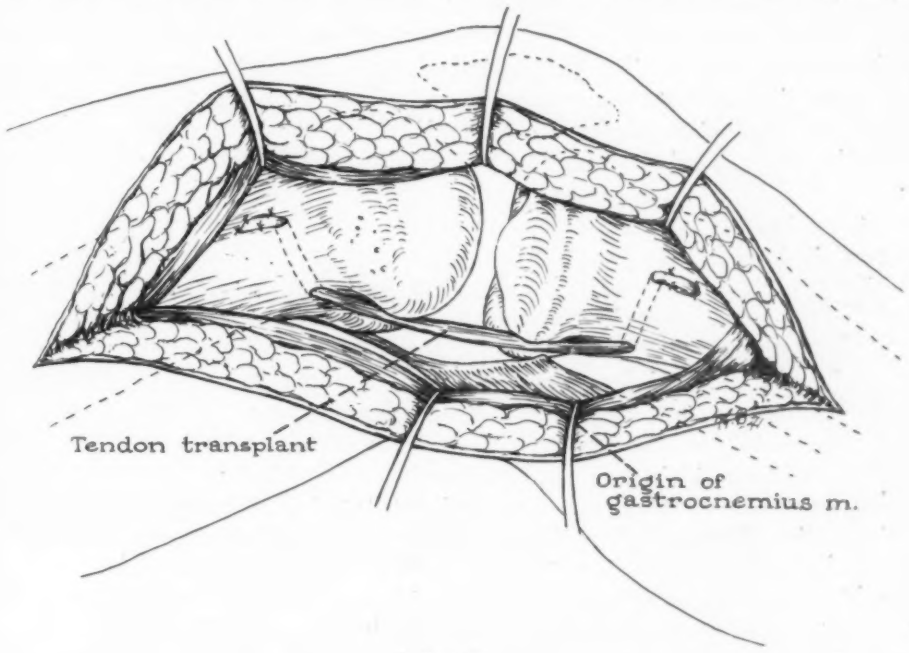

FIG. 6

Diagram of alternative operation. The peronaeus longus tendon, or a tube of fascia lata, passing through drill holes made diagonally backward through the femur and the tibia, is used to form a check ligament to prevent genu recurvatum. This provides a direct support posteriorly, but it will not correct lateral instability.

discontinued, was again operated upon three weeks later. The result was so gratifying in this and in two subsequent cases that it appears worthy of description, and is recommended as another efficient method for the construction of a check ligament to correct genu recurvatum. It has been found preferable to the original method of reconstructing the collateral ligaments in the absence of lateral instability. The deformity and stability of the knee have remained well corrected fourteen years and seven years, respectively, after operation.

The tendon of the peronaeus longus is used as the material for the check ligament. This was found by Henderson to be more efficient than a strip of fascia lata to stabilize recurrent dislocation of the shoulder, and has the added advantage of being less bulky and stronger in proportion to thickness. Probably there is no serious objection to the use of fascia lata rather than the tendon of a strong muscle.

An appropriately long portion of the peronaeus longus tendon, consisting of two-thirds of its thickness, is excised according to the technique described by Henderson. If this muscle is paralyzed, the entire tendon is utilized. It is laid aside in a moist sponge for later use. A longitudinal incision is then made over the medial aspect of the lower end of the

femur, and is continued downward over the medial aspect of the tibia. The periosteum covering the medial condyles of the femur and tibia is incised immediately posterior to the tibial collateral ligament, and the posterior surfaces of the lower end of the femur and upper end of the tibia are exposed subperiosteally. The origin of the inner head of the gastrocnemius is detached from the bone with this dissection. Obliquely directed drill holes are then made through the lower end of the femur, proximal to the epiphyseal plate, and through the upper end of the tibia, distal to the epiphyseal plate, in such a direction that their exits are at the posterior aspects of these bones. While the knee is supported in flexion of 30 degrees, the excised tendon is passed through the drill holes, and the protruding ends are sutured to the anterior margin of the periosteal sheath. Tension should be sufficient to make the tendon taut and to resist extension of the knee beyond an angle of 150 degrees. This direct implantation of a tendon or fascial strip through a hole is more reliable for security than is a superficial cortical or periosteal attachment, and solves the difficulty formerly experienced when dealing with osteoporotic bone. During closure of the wound and application of the plaster bandage, the knee is supported at an angle of 150 degrees. It is expected that there will be some give afterward, allowing complete extension.

In the presence of a weak or paralyzed quadriceps, it is imperative that complete extension of the knee be possible. In fact, a slight back-knee is desired in this situation to provide stability. Accordingly, three weeks after operation the cast is bivalved, and the flexed knee is extended gently by the surgeon. This is not delegated to a physiotherapist, for the surgeon alone can estimate the tautness of the posterior structures and can be guided accordingly in the future stretching needed to obtain complete extension. The knee is then replaced in the bivalved cast in the originally flexed position. Experience has shown that six weeks' protection in the cast is sufficient. The patient is then allowed liberty of movement without weight-bearing. If progress toward obtaining complete extension is slow, gentle stretching by the physiotherapist is instituted until almost complete extension is possible. A convalescent walking brace, limiting extension just short of 180 degrees, is worn for three months.

Since the check ligament passes across the joint to insertions beyond the epiphyseal plates, a pertinent question arises as to the likelihood of an unyielding fascial or tendinous structure causing flexion deformity of the knee with growth. This has not been observed. Perhaps growth may act favorably by maintaining tautness of the check ligament, which would compensate for any possible stretching. Late roentgenograms of the knee after operation have shown no appreciable disturbance of growth. One cannot say with certainty the lower age limit at which a check ligament may be implanted across the epiphyseal line at the knee, but caution would dissuade one from doing it on a patient under the age of twelve.

Tenodesis, as described, has been performed upon three patients, aged ten years, thirteen years, and fourteen years, respectively. The first operation was done in 1931. This patient had a severe forward subluxation of the tibia in addition to genu recurvatum. The knee had remained in good stability when the patient was last seen, three years after operation. The other two patients were operated upon in 1933 and 1940, and were demonstrated before the Clinical Orthopaedic Society in Cleveland in 1941. Neither patient is wearing a brace; there has been no recurrence of deformity; and there is no flexion contracture.

SELECTION OF CASES SUITABLE FOR OPERATION

Stabilization of the knee to correct paralytic genu recurvatum is indicated when correction of the disability would enable the patient to walk without a brace to support the knee; and perhaps it should be done in the mild case, in order to prevent an increasing deformity with ultimate malformation of the tibial condyles. The strength of the quadriceps

is a most important consideration. Mild genu recurvatum is often advantageous in the presence of a weak quadriceps, because it gives stability to the knee. Complete correction of the recurvatum may, therefore, not be desirable when the quadriceps is paralyzed; and one should be cautious in advising operation in the presence of paralysis of the quadriceps, because ability to walk thereafter without a brace would be uncertain. Paralysis of the glutaeus maximus associated with a weak quadriceps is a contra-indication for the operation, because the backward lurching limp at the hip requires a good quadriceps to prevent the knee from giving way. The foot should be stable or should be made so. An excessive equinus deformity must be corrected, because this predisposes to strain at the back of the knee. Mild equinus, however, may be advantageous in the presence of a weak quadriceps.

SUMMARY

Either of the operations herein described is recommended when a bone deformity, consisting of a depression of the anterior articulating surface of the tibia, is not a major factor causing genu recurvatum. In this case, the operation of Brett to elevate the tibial plateau or the osteotomy of Campbell or Irwin would be required. It would seem, however, that these osteoplastic operations would not correct the lateral instability which so frequently accompanies genu recurvatum; nor will a check-ligament type of operation ensure lateral stability unless the lateral as well as the posterior structures are reinforced. The original operation to reconstruct collateral ligaments to a more posterior position on the condyles of the femur meets this requirement, and is the operation of choice when lateral instability as well as genu recurvatum is present. When there is no lateral instability of importance, the alternative operation of reinforcing the posterior structures alone is sufficient, and probably more adaptable.

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THE USE OF ABSORBABLE SUBSTANCES TO OBLITERATE BONE CAVITIES AND AS HEMOSTATIC AGENTS IN OPERATIVE PROCEDURES ON BONES AND JOINTS *

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THE USE OF ABSORBABLE SUBSTANCES TO OBLITERATE BONE CAVITIES

In the course of a project on the use of penicillin in the therapy of chronic osteomyelitis, the authors have resorted to the primary closure of wounds resulting from the surgical procedures. The details of the technique and the results obtained have been reported elsewhere [1,2] and, therefore, need to be described only briefly in this report.

The technique consists of the intramuscular administration of penicillin at three-hour intervals for approximately twenty-four hours prior to a thorough saucerization of the osteomyelitic focus (under tourniquet control, whenever feasible), and the removal of all diseased and scarred overlying soft tissues. After the proper toilet of the wound with saline solution, the cavity is flooded with normal saline containing 250 units of penicillin per cubic centimeter of fluid. The wound is then firmly closed in several layers without drainage. Adjacent sinus tracts are excised, whenever possible, and closed without drainage. If such a procedure is not feasible, the tracts are curetted and their openings are sealed with several sutures. Gauze soaked in penicillin-saline solution is used as a dressing, and the parts are immobilized in a huge compression bandage of sheet wadding, flannel bandage, and adhesive tape. The intramuscular administration of penicillin, started on the day before the operative procedure, is continued uninterruptedly for a period of ten to fourteen days after operation, depending upon the patient's range of temperature and upon the character of healing of the wound. The dosage of penicillin varies with the sensitivity of the micro-organism to the antibiotic. In those instances in which the organisms are sensitive to 0.2 unit or less of penicillin per cubic centimeter, 20,000 units per dose are ordinarily given. When the micro-organisms are resistant to 0.3 unit or more, 30,000 or 40,000 units per dose are given. The concentration of the penicillin used locally has, in all instances, been 250 units per cubic centimeter of normal saline solution. The compression bandage and dressing are usually not disturbed until the tenth day after operation, at which time the wound is usually found to be either completely or very nearly healed by first intention. The sutures are removed at this time.

The treatment of chronic osteomyelitis by saucerization and primary closure of the wound under antibiotic influences has brought with it the problem of control of the hematoma which develops in the resultant bone cavity. The use of intramuscular injections of penicillin before and after the operative procedure and of local applications of penicillin before closure of the operative wound, without drainage, has been found to control infection, if the procedure has been sufficiently thorough, until the hematoma becomes adequately organized to resist infection. It has further been noted that, if the hematoma is too large to be organized rapidly, a sinus results. This reestablishes the cavity and exposes the operative site to reinfection from without, with resultant delay or failure of healing.

Procedure

In an attempt to fill the bone cavity and to control the continued oozing from the operative site, the authors have used absorbable gauze (oxycel) [5,6,15,16] and absorbable

* This work was done largely as a collateral study to a project on the use of penicillin in the treatment of suppurative lesions with special reference to chronic osteomyelitis, under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and the Hospital for Joint Diseases.

TABLE I

TREATMENT OF CHRONIC OSTEOMYELITIC LESIONS, WITH AND WITHOUT THE USE OF ABSORBABLE SUBSTANCES TO OBLITERATE BONE CAVITIES

Case No.	Operative Procedure	Substance Used for Hemostasis and Filling of Cavity	Remarks
7–75	Saucerization of tibia and plastic repair of skin	Oxycel	Healed by first intention. Fluctuation developed at operative site, followed by spontaneous serosanguineous discharge. Healed on forty-eighth day after operation.
10–17	Saucerization of tibia	None	Healed by first intention; serosanguineous discharge on thirteenth day after operation. Healed on thirty-fourth day.
24–35	Saucerization of femur	None	Wound failed to heal; inadequate operative procedure.
25–37	Intra-articular and extra-articular arthrodesis of hip	None	Healed by first intention.
26–40	Resection of metatarsal and toe	None	Healed by first intention.
26–160	Resection of two toes and metatarsal	None	Healed by first intention.
27–41	Saucerization of humerus	None	Healed by first intention; preoperative sinus healed on twenty-ninth day after operation.
30–46	Saucerization of tibia	None	Necrosis of skin at lower angle, due to embarrassed circulation. Healed on fiftieth postoperative day.
33–49	Saucerization of femur	None	Healed by first intention.
34–51	Saucerization of tibia	None	Healed by first intention except for area of atrophic skin; ulcer persisted.
37–54	Saucerization of humerus	None	Slight discharge of serosanguineous fluid. Healed on thirteenth day after operation.
38–55	Saucerization of tibia	None	Slight sanguineous discharge. Healed on fourteenth postoperative day, except for areas of necrosis due to embarrassed circulation. Healed on forty-fourth postoperative day.
41–59	Resection of toe and metatarsal	None	Healed by first intention.
42–60	Saucerization of tibia	None	Slight discharge; healed on twentieth day after operation.
42–61	Saucerization of neck of femur	Oxycel	Healed by first intention on tenth day. Wound moist and irritated, but remained healed.
43–62	Resection of sacro-iliac joint	None	Healed by first intention.
47–66	Saucerization of femur	None	Healed by first intention on thirteenth postoperative day, after spontaneous evacuation of a slight hematoma.
49–69	Saucerization of tibia	Oxycel	Healed by first intention after spontaneous evacuation of small hematoma.
50–73	Saucerization of disarticulated hip and plastic repair of skin	Oxycel	Failure of healing; complete excision of avascular scar not possible. Complicated by severe amyloidosis.
53–78	Saucerization of femur	Oxycel	Failure of healing; sanguineous discharge; possibly due to failure to saucerize a second focus in same femur.
54–79	Saucerization of femur	Oxycel	Considerable bleeding into dressings; wound moist; small stitch abscesses. Healed on thirty-first day after operation.
54–135	Saucerization of humerus	Gelfoam and 1,500 units of thrombin	Considerable sanguineous discharge on fifteenth day after operation. Healed on seventeenth postoperative day.

TABLE I (*Continued*)

Case No.	Operative Procedure	Substance Used for Hemostasis and Filling of Cavity	Remarks
56–82	Saucerization of femur	None	Healed by first intention.
57–83 57–84	Saucerization of humerus and ulna	None	Healed by first intention; wound over ulna somewhat irritated.
62–89	Resection of rib	None	Healed by first intention.
67–96	Saucerization of interphalangeal joint	None	Healed by first intention.
68–97	Resection of second toe and metatarsal and overlying ulcer	None	Slight maceration of skin in web. Healed on forty-first day after operation.
71–166	Saucerization of fused lumbosacral region of spine and buttock	None	Healed by first intention.
73–103	Saucerization of calcaneus	None	Healed by first intention.
75–105	Saucerization of tibia	None	Healed by first intention except for small area which was expected to slough, because of atrophy and embarrassment of circulation of skin.
77–107	Saucerization of femur	None	Healed by first intention.
78–108	Saucerization of tibia and plastic repair of skin	None	Healed on forty-first day after operation, subsequent to spontaneous evacuation of hematoma and necrosis of small area of skin flap.
80–110	Resection of middle half of fibula	Gelfoam and thrombin	Healed by first intention, subsequent to slight bloody discharge and prolonged fluctuation at operative site. This resolved without further discharge.
81–111	Saucerization of femur	None	Healed on fifteenth day after operation except for several small granulating areas which healed on thirtieth day after operation.
84–114	Saucerization of femur	Gelfoam and 1,500 units of thrombin	Healed by first intention.
86–116	Saucerization of lower jaw	Gelfoam and 1,500 units of thrombin	Persistent slight sterile drainage, which was sanguineous at onset.
87–117	Saucerization of femur and plastic repair of skin on opposite side of thigh	Gelfoam and 1,500 units of thrombin	Considerable oozing into dressings. Temperature began to fluctuate to over 103 degrees. Wound explored on fourteenth day. Considerable slough and foul discharge. *Bacillus proteus* isolated at primary and secondary operations. Result: failure.
87–147	Saucerization of femur	None	Wound broke down on twentieth day after operation and hematoma was evacuated. Healed on forty-fifth postoperative day.
89–122	Saucerization of hip joint	None	Wound not dressed for six weeks, when plaster-of-Paris spica was removed. Wound found healed except for some irritation at stitch holes.
90–123	Saucerization of femur	Gelfoam and 1,500 units of thrombin	Severe hemorrhage on seventh postoperative day, necessitating administration of plasma for shock. Diastasis of wound. Secondary closure on thirteenth postoperative day, after evacuation of clot. Slight discharge. Healed on twenty-ninth day.
92–125	Saucerization of tibia and plastic repair of skin	Gelfoam and 1,500 units of thrombin	Skin edges of lower half of wound sloughed. Healed on forty-first day after operation.

TABLE I (*Continued*)

Case No.	Operative Procedure	Substance Used for Hemostasis and Filling of Cavity	Remarks
94–129	Saucerization of tibia	Gelfoam and 1,500 units of thrombin	Serous discharge on thirteenth postoperative day; healed on fifteenth day. Fluctuation on twenty-second postoperative day; spontaneous serous discharge on twenty-fifth day. Healed on thirty-second day after operation.
98–136	Saucerization of radius	None	Healed by first intention.
100–38	Saucerization of tibia	None	Sanguineous discharge on sixth day after operation. Spontaneous discharge of hematoma on twentieth postoperative day. Healed on thirty-first postoperative day.
104–144	Saucerization of femur	None	Fluctuation at operative site on ninth day after operation. Wound healed without discharge.
105–145	Saucerization of tibia	Gelfoam and 1,500 units of thrombin	Spontaneous evacuation of hematoma on eighth day after operation. Healed with persistent fluctuation on thirteenth postoperative day.
105–146	Saucerization of tibia	None	Slight sanguineous discharge on sixth day after operation. Healed on seventeenth postoperative day.
106–148	Saucerization of femur	Gelfoam and 1,500 units of thrombin	Sanguineous discharge and induration at lower angle on eighth day after operation; sinus persisted. Result: failure.
106–159	Saucerization of femur	None	Sanguineous discharge and irritation of wound on eighth day after operation. Spontaneous evacuation of hematoma on eighteenth postoperative day. Sinus persisted. Result: failure.
109–151	Saucerization of distal phalanx of finger	None	Healed by first intention.
113–158	Saucerization of tibia and plastic repair of skin	Gelfoam and 1,500 units of thrombin	Spontaneous evacuation of hematoma on sixth day after operation. Persistent discharge. Healed on fifty-ninth day after operation.
123–176	Saucerization of femur	None	Healed by first intention.

gelatin (gelfoam) [3,4,8]. These substances were left in the wound, to be absorbed eventually by the tissues. In addition, they were used as vehicles for penicillin. In some instances, gelfoam was used as a partial filler of the cavity, in conjunction with thrombin to control the oozing and with penicillin to control the infection.

The technique of the use of these substances had to be somewhat different from that described by other investigators [7,10–14], who used these substances in the presence of active oozing in soft tissues. Since the majority of the authors' patients were operated upon under tourniquet control, which was not released until after the compression bandages had been applied, the operative fields were dry. Oxycel was packed firmly into areas where bleeding was anticipated after release of the tourniquet. These sites were usually the exposed medullary canal openings and the metaphyseal areas. The wounds were then flooded with normal saline, containing 250 units of penicillin per cubic centimeter of fluid, closed without drainage, and dressed as described, before the tourniquet control was released.

Gelfoam was used under circumstances similar to those existing in the use of oxycel, and differed only in those steps inherent in the use of absorbable gelatin. Fifteen hundred

units of thrombin was usually dissolved in fifteen cubic centimeters of normal saline, containing 250 units of penicillin per cubic centimeter of fluid. The gelfoam was then immersed in the thrombin-penicillin-saline solution. When it had been thoroughly soaked, it was kneaded to expel any remaining bubbles of air, and reimmersed in the thrombin-penicillin-saline solution until it had absorbed the maximum amount of fluid. The gelfoam was then pressed into sites from which bleeding was anticipated. Since gelfoam becomes gelatinous at this stage, firm packing could not be effected and close adhesion could not be obtained. Here, too, the wounds were flooded with saline solution containing penicillin, closed firmly without drainage, and dressed as described previously, before the tourniquet control was released.

Results

In Table I are listed all of the cases with chronic osteomyelitic lesions in which operations were performed during the greater part of the project and in which the wounds were closed without drainage. Included are instances in which oxycel or gelfoam was used to provide partial obliteration of the postoperative dead space and also to provide a hemostatic agent to lessen the amount of oozing, subsequent to the closure of the wound. Included in this series are also those lesions in which the hemostatic and filling agents were not used. These may, therefore, be considered as control cases, because they were in a general way similar to the cases in which absorbable substances were used.

In thirty-six of the total of fifty-three operative procedures, no absorbable substances were utilized. In seventeen of these, healing by first intention had occurred on the tenth postoperative day, at the time of removal of the sutures, without any complicating factor affecting the nature or time of healing. In twelve instances there were complicating hematomata, accompanied by the spontaneous discharge of blood or serum or some slight irritation of the wound, with resultant delay, but nevertheless good healing of the wounds. In five instances, all of which involved lesions of the tibiae, there was skin necrosis due to embarrassment of circulation, incidental to the operative procedures, in areas in which the circulation had been somewhat embarrassed, although competent, before the operation. Some of these complications were anticipated. All except one of these lesions have eventually healed without further operative interference. There were two failures of healing, due to inadequate operative procedures.

In six of the fifty-three operative procedures, oxycel was used as a partial filler of the resultant dead space and as a hemostatic agent. There was no instance of healing by first intention without complication. In four lesions, spontaneous drainage of hematomata or some other irritation of the wound delayed healing. In two instances, there were failures of healing, due to inadequate removal of the disease focus.

In eleven of the fifty-three operative procedures (Table I), gelfoam was used as a hemostatic, as a vehicle for penicillin, and for partial filling of the dead space resulting from the surgical excision. One of the eleven lesions had healed by first intention at the time of removal of the sutures, on the tenth postoperative day. In nine lesions, spontaneous evacuation of hematomata or other complicating irritations resulted in some delay of wound healing. In one of these nine (Case 90–123), the only one in the entire series, a severe hemorrhage occurred on the seventh day after operation, necessitating the immediate administration of plasma to combat shock, and the eventual operative removal of the blood clot and successful secondary closure of the wound without the use of any hemostatic or filling agent. One lesion (Case 92–125) of the tibia which, in addition to the saucerization, was subjected to a dermatoplasty, was complicated by a sloughing of part of the wound edges, due to embarrassment of the circulation. This lesion eventually healed well without a further operative procedure. In another instance (Case 87–117) there was considerable oozing into the dressings and irregularities of temperature, necessitating the operative exploration of the wound. Considerable slough and foul discharge

were encountered. Cultures of the wound at the primary and secondary operative procedures yielded *Bacillus proteus*. Another lesion (in Case 106–148) failed to heal. Subsequent reoperation without the use of an absorbable agent similarly resulted in failure of healing.

Comment

The authors readily appreciate that the six lesions in which oxycel was utilized and the eleven instances in which gelfoam was used are but a small series, from which final conclusions cannot be drawn. A comparison of these cases with those in which the absorbable substances were not used clearly indicates that the proportion of primary healing, without any complicating hematomata or other irritations of the wounds, is considerably less in the presence of these substances. The clinical difference in the character of the healing has led the authors to abandon the use of oxycel and gelfoam as fillers for bone cavities.

In this connection, Lattes and Frantz have reported animal experiments which indicate that absorbable gelatin sponge (gelfoam) showed "a slight delay in healing [of fractures] as compared with those treated with fibrin foam and with the controls, but in no case as marked as those treated with oxidized cellulose. . . . There seems to be little doubt that the presence of oxidized cellulose in the immediate vicinity of a fracture interferes with the normal processes of repair of bone." The quantities of oxycel and gelfoam used in the authors' cases were probably greater than those used by Lattes and Frantz. This may very well be an additional factor in the delay of bone repair, suggested by our series of cases.

THE USE OF ABSORBABLE SUBSTANCES AS HEMOSTATIC AGENTS IN OPERATIVE PROCEDURES ON BONES AND JOINTS

Introduction

In addition to using oxycel and gelfoam as absorbable substances to obliterate bone cavities, the authors have also utilized these substances as hemostatic agents in the presence of troublesome oozing and uncontrollable bleeding during surgical procedures on various bones and joints. The use of these substances as hemostatic agents is more in keeping with the purposes for which they have been developed and utilized by the several investigators on this subject, in contradistinction to their use as a filler for dead spaces.

Procedure

Oxycel was used in the conventional manner described by the original investigators [5,6,7,13,14]. Small pledgets of the oxidized gauze were applied by the gloved finger or by a superimposed piece of ordinary gauze, which was subsequently removed. Upon coming into contact with the bleeding area, the oxidized gauze rapidly underwent a change and became converted into a black, tarry, very friable substance which effectively controlled the oozing or bleeding. In all but a very few instances, the substance was left in place and the wounds were closed without drainage. In all instances, intramuscular penicillin was administered during the preoperative and postoperative periods, and local penicillin was used in the manner noted.

Gelfoam was used as a vehicle for thrombin and penicillin. After preparation of the substance, the pledgets were applied to the bleeding area under pressure of the gloved finger or of a superimposed piece of gauze. Difficulty was at times encountered in obtaining satisfactory packing, because of the gelatinous nature of the prepared gelfoam. All of these operative procedures were carried out under antibiotic control.

TABLE II

HEMOSTASIS WITH OXIDIZED GAUZE AND ABSORBABLE GELATIN IN OPERATIVE PROCEDURES ON VARIOUS BONES AND JOINTS

Case	Operative Procedure	Substance Used	Remarks
F. D. 95–130	Resection of first toe, metatarsal and cuneiform bones, and overlying inflammatory tissue for tuberculosis	Oxycel	Lesion was so extensive that it could not be closed, regardless of releasing incisions. Severe oozing was readily controlled by oxycel, used as a superficial dressing.
F. D. 95–131	Mid-calf amputation for tuberculosis of foot	Gelfoam and thrombin	Oozing well controlled. Wound closed without drainage. Skin traction applied. Wound healed by first intention.
J. J. M. 96–132	Saucerization and arthrodesis of hip for tuberculosis	Gelfoam and thrombin	Oozing well controlled. Wound closed without drainage. Healed except for stitch abscess, slight serous discharge, and two small areas of persistent granulations, on fifty-sixth day after operation.
A. B. 97–133	Evacuation of soft-tissue abscess (*Staphylococcus aureus*)	Gelfoam and thrombin	Wound closed without drainage. On the tenth day after operation, wound was healed except at its upper angle. Complete healing on the fifteenth postoperative day.
A. P. 53–102	Saucerization of femur (15-inch incision) for osteomyelitis	Oxycel	No tourniquet used. Oozing readily controlled by four pieces of oxycel, which were removed prior to closure of the wound without drainage. Wound healed on thirtieth day after operation. (See Table I, Case 53–78.)
L.	Exploration for herniated nucleus pulposus and Hibbs' spine fusion, reinforced by double clothespin bone graft	Oxycel	Troublesome oozing readily controlled. Wound healed by first intention. Spontaneous evacuation of small hematoma, three weeks after operation, followed by rapid healing of wound.
S. L.	Hibbs' spine fusion for tuberculosis	Oxycel	Oozing readily controlled. Wound healed by first intention.
T. W. 14–23	Saucerization of scapula for tuberculosis	Oxycel	Oozing readily controlled. Wound closed without drainage. Spontaneous evacuation of serosanguineous fluid on the eighth postoperative day; wound failed to heal.
S. H. 88–118	Excision of greater trochanter for tuberculosis	Gelfoam and thrombin	Oozing readily controlled. Wound closed without drainage. Spontaneous evacuation of a hematoma on eleventh day after operation. Culture of wound at operation sterile. Wound failed to heal.
L. S. 91–124	Interinnomino-abdominal amputation for osteogenic sarcoma superimposed on Paget's disease of innominate bone	Gelfoam and thrombin	Troublesome oozing in perineal region and from stump of ilium readily controlled. Portion of skin flap sloughed.
M. Z. 93–127	Interinnomino-abdominal amputation for recurrent osteogenic sarcoma of stump of thigh	Oxycel, gelfoam, and thrombin	Troublesome oozing readily controlled. Wound healed by first intention except for small area of sloughing of skin flap, due to embarrassed circulation.
H. C. 117–169	Biopsy for osteogenic sarcoma of coracoid process	Oxycel	Troublesome oozing readily controlled. Wound healed by first intention. Interscapulothoracic amputation seven days later. Wound healed by first intention. Specimen showed no evidence of irritation incidental to presence of oxycel.
A.	Biopsy for osteogenic sarcoma of scapula, superimposed on Paget's disease	Oxycel	Troublesome oozing readily controlled. Wound healed by first intention. Specimen obtained at site of interscapulo-thoracic amputation showed no evidence of irritations due to oxycel.

TABLE II (*Continued*)

Case	Operative Procedure	Substance Used	Remarks
R.	Subtotal resection of ilium for osteomyelitis	Oxycel, gelfoam, and thrombin	Serious bleeding of superior gluteal artery occurred. Ligation impossible because of retraction of artery into sciatic notch. Bleeding partially controlled by hemostats. Packing with gelfoam proved impractical, because of its gelatinous nature. Packing with oxycel controlled the bleeding and made possible the completion of the operation.

Results

In Table II are listed all of the operative procedures in which either oxycel or gelfoam was used for the specific purpose of controlling troublesome oozing or frank bleeding. In all instances, hemostasis was satisfactorily and readily accomplished. The application of oxycel proved to be simpler and more effective than that of gelfoam. The gelatinous nature of the latter substance made firm packing difficult.

It should be further observed that, of seven instances in which oxycel alone was used as a hemostatic agent, only four wounds were found to be healed by first intention at the time of removal of the sutures. These wounds remained healed without further complications. In two of these cases, amputations were performed at the end of one week, thus shortening the period of observation of the wounds. All of the wounds in which oxidized gauze was used eventually healed satisfactorily, with the exception of two which were of a tuberculous nature. These failures cannot be attributed to the use of oxycel.

Of five instances in which gelfoam and thrombin were used as the hemostatic agent, only one healed by first intention and remained healed without any further complications. Three of the wounds eventually healed satisfactorily, subsequent to the development of complicating hematomata or skin necroses. These complications are not attributable to the use of the hemostatic agent. The fifth instance ended in failure of the wound to heal, probably as a result of the sinus formed by the hematoma and the resultant secondary infection of the wound, which at the time of operation was sterile.

In the remaining two cases presented in Table II, both oxidized gauze and absorbable gelatin and thrombin were used for the production of hemostasis. In one of these (M. Z.), a portion of the skin flap became necrotic for reasons unrelated to the use of the hemostatic agents. In the second case (R.), gelfoam proved to be ineffective in the production of hemostasis. The wound eventually broke down because of the devitalization of a portion of the bone which had been left in place.

Comment

The use of oxidized gauze or absorbable gelatin with thrombin for hemostasis, in the presence of troublesome oozing and bleeding, has proved effective in difficult circumstances. The use of oxidized gauze is simpler than the use of absorbable gelatin and thrombin. The effectiveness of gelfoam has been found to be increased by investigators [10,11,12] who have used suction to make it adhere to the bleeding area. The authors' experience is limited to the simple application of the substance to the bleeding surface, by pressure of the gloved finger or of an overlying piece of gauze, which is subsequently removed.

It is also apparent from our limited experience that the use of these substances complicates the healing of the surgical wounds in an appreciable number of instances. These complications consist in the spontaneous evacuation of accumulations of blood and serum, with resultant temporary partial disruption of the wound. In at least one instance,

ultimate failure of healing occurred as a result of secondary infection of such a temporarily disrupted wound. One should, therefore, weigh these possibilities carefully before resorting to the use of these hemostatic agents which, under difficult circumstances, are nevertheless of inestimable value in the control of oozing and bleeding.

CONCLUSIONS

1. The use of oxidized gauze or absorbable gelatin as a vehicle for thrombin and penicillin in filling dead spaces or bone cavities appears to be inadvisable, from the authors' limited experience, because of the large proportion of complications interfering with the healing of the surgical wounds by first intention.

2. The use of oxidized gauze or absorbable gelatin with thrombin as hemostatic agents in the presence of troublesome oozing and bleeding is advisable, and at times invaluable, notwithstanding the fact that the final healing of the wound may, in a considerable proportion of instances, be delayed by temporary partial disruption incidental to the evacuation of collections of blood and serum.

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EXPERIENCES WITH EPIPHYSEAL ARREST IN CORRECTING DISCREPANCIES IN LENGTH OF THE LOWER EXTREMITIES IN INFANTILE PARALYSIS

A Method of Predicting the Effect*†

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Discrepancy in length of the lower extremities, if it exists to any considerable degree, is disabling. In infantile paralysis, this disability is greatly exaggerated by the associated paralysis and related skeletal abnormalities; so that measures to equalize the length of the extremities take on added importance.

When growth is complete, the only procedures available are direct lengthening or shortening of one of the long bones. In the growing child, however, the possibility occurs of modifying growth. The ideal arrangement would be to stimulate the growth of the shorter limb. Since no feasible method of accomplishing this exists at present, measures designed to inhibit the growth of the longer limb must be chosen. Surgical epiphyseal arrest, or epiphyseodesis, was first described by Phemister in 1933. This has proved to be a practical method of inhibiting growth, although deformities occurring after the procedure in certain instances have been described by Straub, Thompson, and Wilson, and by Regan and Chatterton. Roentgen irradiation has been shown to inhibit the growth of the epiphyses [2, 3, 4]. Although the use of such a means to affect growth in the child was proposed by Judy, it remains to be demonstrated that undesirable effects do not arise from the irradiation and that its action on growth can be well controlled.

The important problem in surgical arrest is to choose the site of the procedure at the particular age which will allow equalization in length. This necessitates an ability to predict, within a practical amount, the growth in the lower extremity which will occur from various ages until maturity, as well as to estimate the proportion of growth which will be inhibited by the arrest. Although the procedure itself inhibits the growth of the longer limb, the index of its effect on the relative lengths of the extremities is based upon the growth of the shorter extremity.

Various techniques of predicting growth have been proposed. Hatcher adapted the Baldwin tables to obtain a derived length of the extremity[5], and used a percentage from each epiphysis, as described originally by Digby. Gill and Abbott described a more complex method, which was likewise based upon a derived length for the extremity. They emphasized the importance of using skeletal rather than chronological ages in prediction. White and his associates suggested a simplified method, in which they proposed that the obliteration of either the upper tibial or the lower femoral epiphysis resulted in a loss in growth of one-quarter inch to three-eighths of an inch per year, with the assumption that growth terminated at the age of sixteen in girls and at seventeen in boys.

No method, however, has been based upon actual measured lengths of the femur and of the tibia; in fact, the authors are unable to locate published curves of growth of the femur and tibia, through the period of maturation, other than those which they presented recently[1] (Table I).

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1947.

†This study was aided by a grant from The National Foundation for Infantile Paralysis, Inc., New York, N. Y.

TABLE I

AVERAGE LENGTHS OF THE BONES OF THE LOWER EXTREMITY AS MEASURED FROM ORTHOROENTGENOGRAMS

Skeletal Age (*Years*)	Femur			Tibia		
	Percentile*			Percentile*		
	10th	50th	90th	10th	50th	90th
Girls						
5	24.7	26.1	27.6	19.2	20.4	21.8
6	26.7	28.2	30.2	21.0	22.4	23.8
7	28.6	30.2	32.6	22.6	24.3	25.7
8	30.6	31.9	34.6	24.0	25.2	27.3
9	32.4	34.0	36.1	25.1	26.9	28.9
10	33.4	35.6	37.7	26.0	28.2	30.5
11	35.0	37.4	40.1	27.5	29.4	32.2
12	36.3	39.2	41.9	28.8	31.0	33.7
13	38.0	41.2	43.9	30.3	32.8	35.6
14	39.5	41.8	44.4	31.0	33.0	36.2
15	40.3	42.3	44.8	31.4	33.0	36.6
16	40.1	42.3	45.4	31.2	33.6	36.9
Boys						
5	24.2	25.6	26.8	18.8	20.3	21.5
6	26.0	28.0	29.2	20.3	21.9	23.7
7	27.8	29.8	31.6	21.8	23.5	25.4
8	29.6	32.1	33.6	23.4	25.1	27.0
9	31.8	34.1	36.1	24.8	26.5	28.6
10	33.7	35.7	38.2	26.0	28.0	30.1
11	35.1	37.4	40.0	26.9	29.2	31.2
12	36.6	39.3	42.2	28.3	30.6	33.2
13	38.5	41.2	43.9	29.8	32.8	35.0
14	40.2	43.5	46.8	30.9	34.6	36.5
15	42.6	45.4	47.7	33.2	36.0	38.1
16	42.8	46.6	49.4	33.4	37.0	39.2
17	42.6	45.8	49.6	32.6	37.0	39.1
18	42.9	45.8	49.4	32.5	37.0	39.0

*If, in a group of cases, a particular measurement is distributed on the basis of size, the dimension of the individual which is larger than 90 per cent. and smaller than 10 per cent. of the cases may be said to define the ninetieth percentile for the distribution. Similarly, the "fiftieth percentile" describes the size of the middle individual (the median),—the case above and below which lie one-half the cases in the entire series. The "tenth percentile" indicates the level below which lie 10 per cent. of the measurements for the group, and above which lie 90 per cent.

It is the purpose of this communication to report a method of prediction, for use in epiphyseal arrests, which is based upon cumulative roentgenographic measurements of the femur and of the tibia in growing children. It is proposed, also, to outline the experiences with epiphyseal arrests at The Children's Hospital, Boston, regarding both the accuracy of the predicted effect and the incidence of deformities. In all references in this paper to arrest of the proximal tibial epiphysis, it is to be inferred that it is accompanied by arrest of the upper fibular epiphysis.

The chart which is presented for use in prediction must be considered a tentative one, and it will be revised as more data are accumulated. It represents a part of the

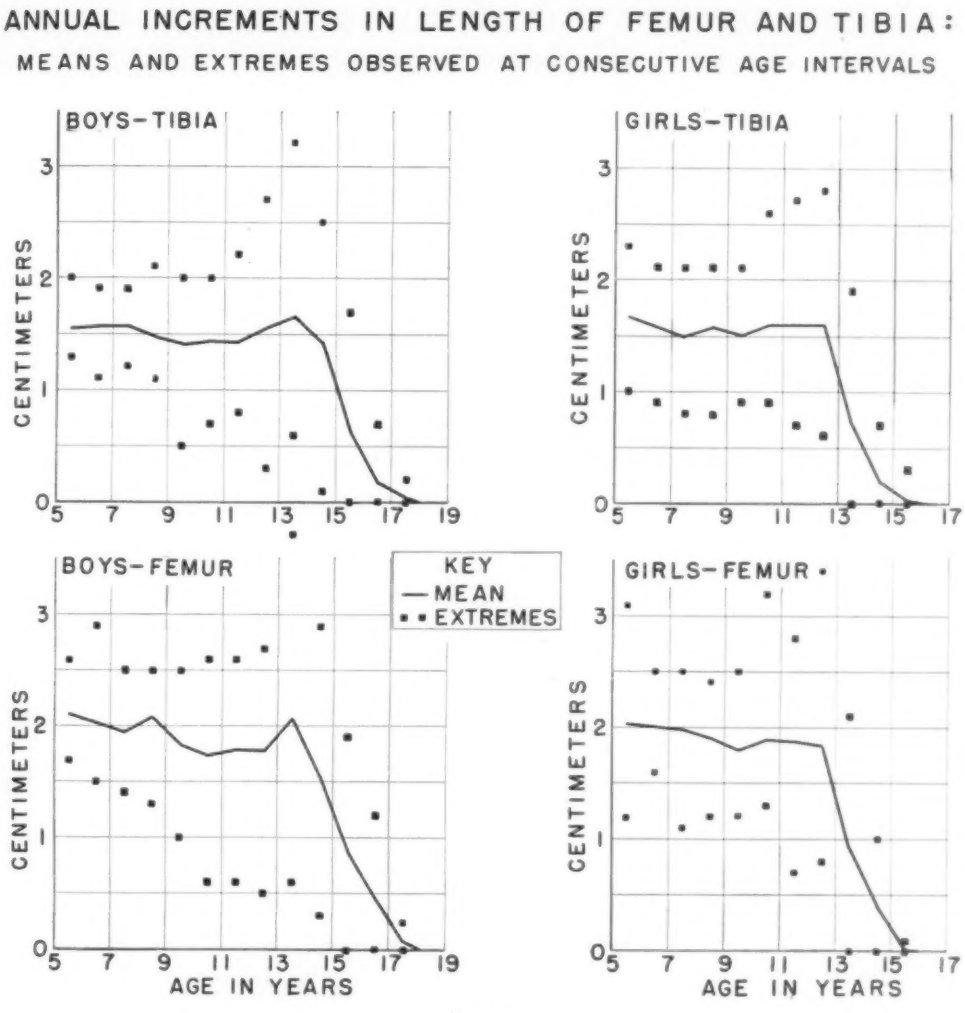

FIG. 1

These values for the annual increments of the bones of the lower extremity constitute the basic data from which the prediction curves were derived. All measurements were made from orthoroentgenograms, which give the true lengths of the bones.

material from a study of growth which has been in progress since 1940. This study involves approximately 700 children, 87 per cent. of whom have residual paralysis in one lower extremity with a normal extremity on the other side; and it also includes observations on 158 normal children, who are the subject of study in the Department of Maternal and Child Health, Harvard School of Public Health.

Studies of growth should be longitudinal,—that is, they should follow the same individual throughout the period of growth, until maturity. The present study follows this principle. However, a sufficient time has not elapsed for the tables to be constructed from completely longitudinal data; and the report represents a combination of limited longitudinal observations of the various children.

The study includes various measurements of the children, performed at regular intervals. Orthoroentgenograms of the femur and of the tibia of each child are taken at yearly intervals; in certain cases they are taken as often as once every three months. This technique of roentgenographic measurement has been described by Green, Wyatt, and Anderson, and is accurate enough to allow the recording of such quarterly increments of growth. For the purposes of this report, the lengths of the bones, as measured roentgenographically,

TABLE II

CENTIMETERS OF CORRECTION TO BE DERIVED FROM ARREST OF THE DISTAL FEMORAL OR THE PROXIMAL TIBIAL EPIPHYSIS
(Tentative Table, January 1947)

Skeletal Age (*Years*)	Distal Femoral Epiphysis			Proximal Tibial Epiphysis		
	Low	Average	High	Low	Average	High
			Girls			
8	6.7	7.4	8.1	4.4	4.9	5.4
9	5.4	6.1	6.8	3.4	4.0	4.5
10	4.1	4.8	5.5	2.6	3.2	3.7
11	2.8	3.5	4.2	1.7	2.3	2.8
12	1.5	2.2	2.9	0.8	1.4	1.9
13	0.2	0.9	1.6	0	0.6	1.1
14	0	0.3	0.7	0	0.1	0.3
15	0	0	0	0	0	0.1
			Boys			
10	6.1	7.1	8.1	4.0	4.7	5.4
11	4.9	5.9	6.9	3.2	3.9	4.6
12	3.7	4.7	5.7	2.4	3.1	3.8
13	2.4	3.4	4.4	1.5	2.2	2.9
14	0.8	1.8	2.8	0.6	1.3	2.0
15	0	0.7	1.7	0	0.4	1.1
16	0	0.3	0.8	0	0.1	0.4
17	0	0	0.2	0	0	0.1

form the essential data. Observations of the patients who have had epiphyseal arrests include lateral roentgenograms of the knees, taken either semiannually or annually until the time of epiphyseal closure.

DERIVATION OF THE METHOD

The method of predicting the effect of epiphyseal arrests which the authors are proposing is based upon a cumulative series of the annual increments in the growth of the long bones of the lower extremity between consecutive ages (Fig. 1). These increments have been computed separately for the femur and for the tibia, and are subdivided as to sex. Measurements were derived from three to six annual orthoroentgenograms of the normal lower extremity of each of seventy-one boys and fifty-one girls with anterior poliomyelitis, and from eight to ten consecutive yearly roentgenographic measurements of twenty boys and eighteen girls who are normal individuals. The average number of increments for each age level was thirty. The extremes are recorded in graphic form, as are the averages. In the derivation of these original average increments, to avoid criticism, only those individuals were used whose chronological ages corresponded to the skeletal ages, as evaluated by the method of Todd*.

For practical usage, curves were constructed to show how much correction might be

*Children with markedly retarded or advanced maturation were placed in a separate series, and the ages of all the individuals in this group were adjusted to conform to their skeletal ages. Yearly increments of bone lengths, derived for this series by the use of skeletal age, corresponded so closely to those for the group which was used that the two could have been combined, if skeletal age had been used for the entire distribution. This, with other evidences which will be discussed later, emphasizes the importance of the assessment of relative skeletal maturity in considerations of growth.

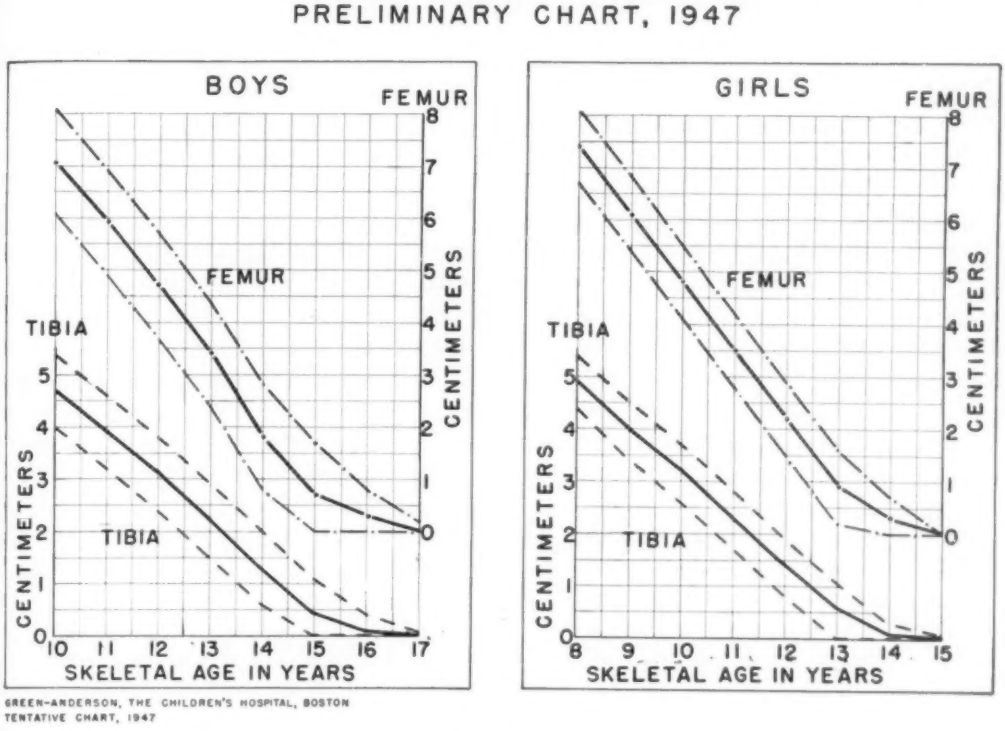

FIG. 2

The amount of growth to be eliminated after epiphyseal arrest can be estimated from this chart. The central line represents the average correction; the secondary lines, the useful range. The extremes are not indicated.

expected at each age from an arrest of either the lower femoral or the upper tibial epiphysis (Fig. 2 and Table II). The proportion of growth of the femur assigned to the lower femoral epiphysis was 70 per cent.; the upper tibial epiphysis was assigned 56 per cent. of tibial growth. These were the averages obtained from a small number of cases which had measurable transverse lines of temporary growth disturbance evident at the ends of the bones. These percentages correspond closely to the original figures of Digby, and to the amounts proposed by others. The prediction chart (Fig. 2) represents a product of the cumulative average annual increments of growth derived from a particular bone and the percentage which the specific epiphysis contributes to growth. The dense central line represents the average correction to be expected from an epiphyseal arrest at the corresponding skeletal age on the chart; a derived range is also indicated for each age level*.

In the use of the chart, various factors can modify the position between the ranges, which will be chosen as the amount predicted for a particular individual. A tall person with long legs, for example, should approach the upper limit of the predicted amount; a short individual, the lower range. Likewise, an individual with a high percentage of inhibited growth in the affected lower extremity would be expected to receive less correction than one whose coefficient of inhibited growth is less; and, therefore, the predicted amount will be adjusted toward the lower figure for the age. When a patient has not had accurate measurements long enough for the percentage of retarded growth to be determined, it may be approximated by relating the existing shortening to the estimated growth since

*Because no case in this series has yet been observed over the entire age range covered by the chart, it is impossible at this time to present actual values for the extremes. An artificial range of predictions is, therefore, included, which has been derived from the standard deviations computed at each annual interval.

the onset of the disease. (In the patients of this series with 75 per cent. or less of musculature remaining, the average retardation of the affected extremity was 10 per cent. in the femur and 12 per cent. in the tibia.) Theoretically, mathematical formulae should be applied to correct these variants, but more data are necessary before such precise adjustments can be made. Shifting the position on the chart within the range indicated for the individual's age, according to the factors mentioned, has worked in practice. As an aid in estimating the relative bone lengths in a given child, a table is included here of the average lengths of the femur and the tibia, derived from orthoroentgenographic measurements (Table I).

The curves of prediction of the effect of epiphyseal arrest presented here do not go below the ages of eight years for girls or ten years for boys. This is an adequate age range for the correction of discrepancies in length, due to infantile paralysis. In the series under study, there have been no discrepancies greater than thirteen centimeters. Arrest at the minimum ages would effect as much correction as this; and it is doubtful whether it would be desirable to deprive an individual of more than five inches in total height in order to equalize the length of his extremities.

The chart (Fig. 2) is based upon the annual increments of growth of a normal lower extremity, rather than upon the average correction observed after epiphyseal arrest, for two reasons. In the first place, a larger group of measurements could thus be used, which gave more reliable averages and ranges in predicted values; in addition, if the corrections obtained from epiphyseal arrests were used, the figures would contain certain uncontrollable variables, which would depend upon the relative effectiveness of the epiphyseal arrest itself.

The average correction after epiphyseal arrest in this series of patients was 65 per cent. in the distal portion of the femur, and 46 per cent. in the proximal portion of the tibia. If these percentages, which are computed on the basis of the growth of the paralyzed limb, were corrected on the basis of the average coefficient of inhibition which has been observed in the paralyzed extremities, the values would be 69 per cent. of normal femoral growth and 52 per cent. of normal tibial growth. These figures are remarkably similar to the average values used in the chart of prediction—70 per cent. and 56 per cent., respectively—particularly when one considers that the figures obtained from epiphyseal arrests represent averages and, therefore, must include some cases in which an effective fusion has been slow in developing.

RELATIVE SKELETAL MATURITY AND AGE AT TIME OF EPIPHYSEAL CLOSURE

Early in this study of growth, the authors discovered that it was essential to make some sort of assessment of the relative maturity of each individual. The method proposed by Todd has been found to be the most valuable guide which exists at this time, although it has certain limitations. The importance of using skeletal age, rather than chronological age, in prediction may be illustrated by comparing the effect of femoral arrest in two girls of the same chronological age. In Case A, with a chronological age of eleven and a skeletal age of eleven, a correction of 3.0 centimeters was obtained. In Case B, with a chronological age of eleven years and four months but with a skeletal age of thirteen years and six months, only 0.9 centimeter of equalization was accomplished.

It was the authors' rule to use the skeletal age in predictions, first, if the skeletal age deviated nine months or more from the chronological age or, second, if it varied consistently in serial examinations by as much as six months.

The importance of assessment of the degree of skeletal maturity is further emphasized by considering the age at which the epiphyses of the lower extremities fuse. As judged by serial roentgenograms, this fusion occurred at an average skeletal age of fifteen years and three months in girls and of seventeen years and three months in boys. In all instances, the fusion was observed within one year of these skeletal ages, whereas the chronological

age at which epiphyseal fusion occurred varied tremendously, covering a range of four or five years. Very little growth occurred during the year preceding the closure of the epiphyses, so that the skeletal ages of fourteen years and three months in girls and sixteen years and three months in boys can, for practical purposes, be used as the ages at which growth of the lower extremities terminates.

ACCURACY OF PREDICTION

Although the effect of epiphyseal arrest in correcting discrepancy can be determined once growth is complete, not all cases in this category can be used in testing the accuracy of methods of prediction.

Seventy-seven cases of epiphyseal arrest in this group have been followed through the period of completion of growth in the lower extremities; however, for the purpose of evaluating predictions, it was necessary to omit cases in which accurate serial roentgenographic measurements were not available, those in which the skeletal age was not recorded at the time of the procedure, and individuals in whom other operations complicated the measurements. Likewise, patients were omitted in whom the paralytic involvement was bilateral; those in whom the epiphyseal arrest was definitely slow in producing its effect, as determined by postoperative roentgenograms; and those in whom a postoperative deformity occurred.

Satisfying the demands were forty-one arrests, performed on twenty-nine patients. The other arrests were used in evaluating the result of the procedure, but not in evaluating the method of prediction. The general pattern of the action of the arrest in each of these forty-one operations was nearly always parallel to the predicted curve (Figs. 3-A and 3-B). Of the 190 points representing levels of prediction at the various ages, only 4 per cent. were outside the indicated range, and in those the deviations were of minor degree.

The accuracy of this method of prediction was compared with that of four other methods of estimating the effect of epiphyseal arrest:

1. The Baldwin-Hatcher table, assuming that the distal portion of the femur contributes 40 per cent. and the proximal portion of the tibia 27 per cent. of the growth in the lower extremity.
2. The Gill-Abbott method.
3. White's method, assuming that the distal portion of the femur contributes three-eighths of an inch per year and the proximal portion of the tibia contributes one-quarter inch per year until the age of sixteen years in girls and of seventeen years in boys.
4. A method utilizing a fixed yearly increment of growth and skeletal age.

The fourth method might be considered a modification of the method of White, and will be described in detail. In all instances, except the original method of White, skeletal ages rather than chronological ages were used (Fig. 4).

The Baldwin-Hatcher table gave a high figure for the predicted result in the boys in this series, but the girls in the group obtained corrections quite similar to those predicted. When this method was employed, in conjunction with a correction for skeletal age, predictions were more accurate than one would anticipate, when it is considered that the table is derived from anthropometric measurements. Baldwin's measurements, which were used by Hatcher, indicate that extremities grow more rapidly in boys than in girls; the authors' data, on the other hand, indicate that boys grow at essentially the same rate, but continue to grow two years longer than girls.

The Gill-Abbott method, although more complicated, has the virtue of being the only one in which the height of the individual is taken into consideration. Their predictions coincided very well with the results obtained in the authors' cases, with the exception of boys' femora, in which the amount predicted exceeded greatly that which was obtained in this series.

White's method has the great advantage that predictions are made without a chart;

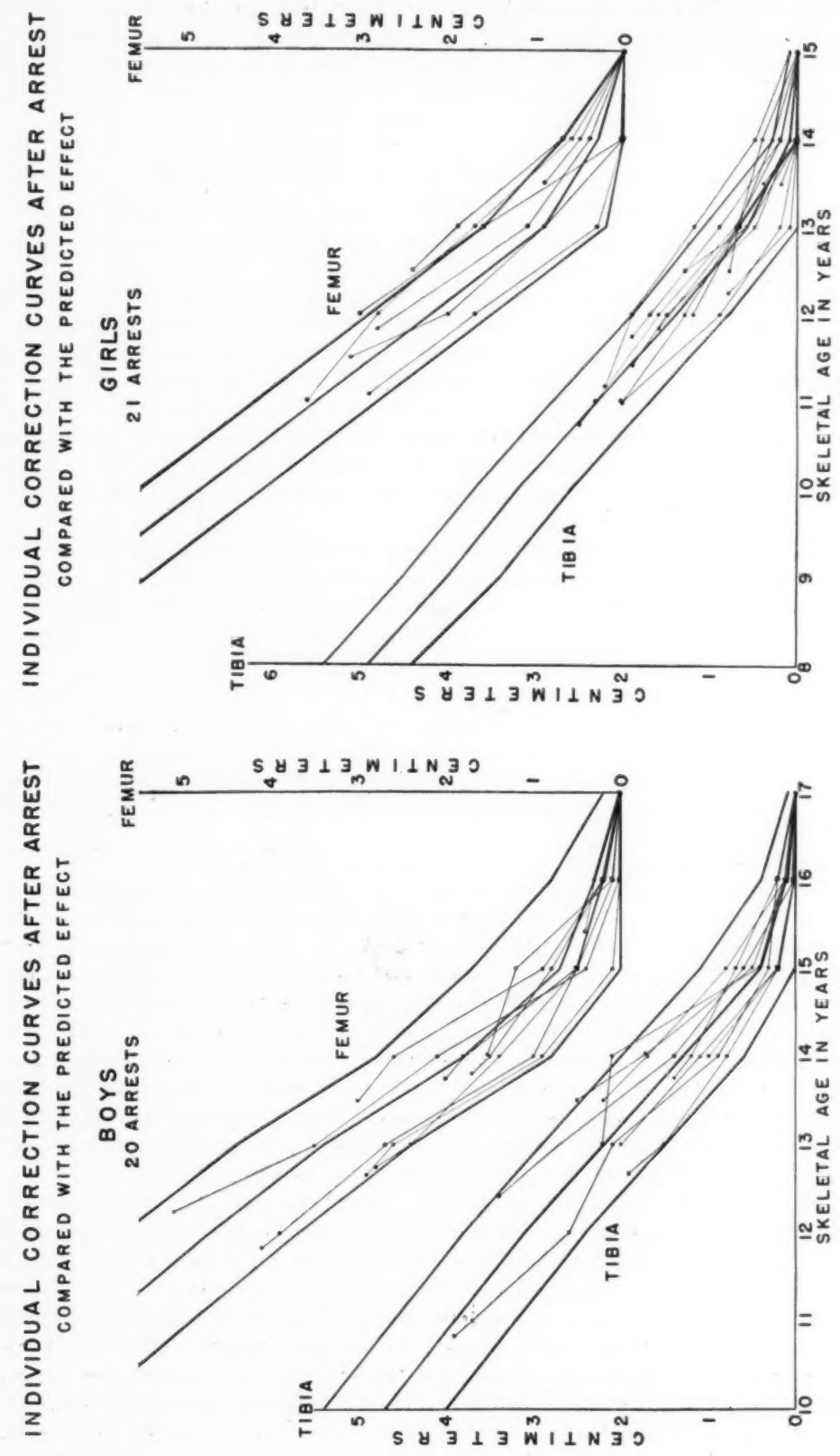

FIG. 3-B

FIG. 3-A

The amounts of correction observed at consecutive skeletal-age levels, after forty-one epiphyseal arrests, follow the pattern indicated by the prediction curves.

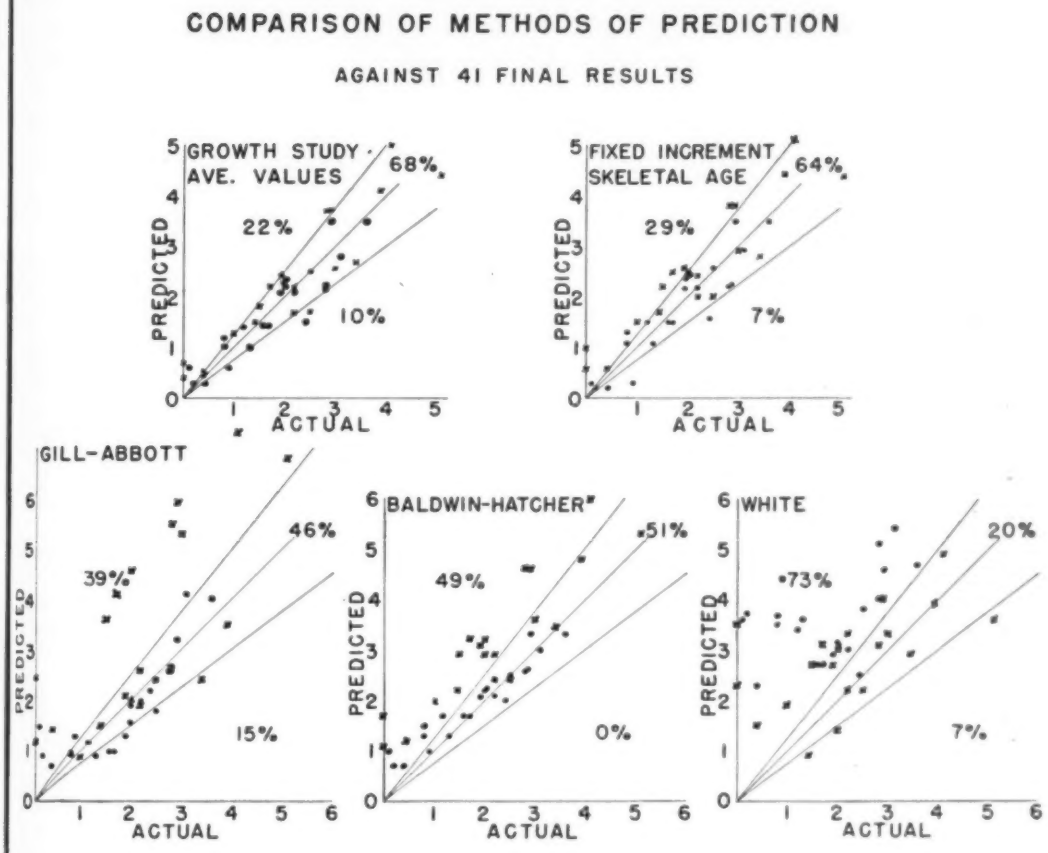

FIG. 4

Each of these charts has been constructed with a diagonal line, indicating perfect agreement between actual and predicted results; and with two other lines, spaced so as to include all cases within a 25 per cent. error of prediction. Arrests on boys are indicated by a cross; on girls, by a solid circle.

The forty-one final results in the test series corresponded more closely to the values from the authors' prediction chart (growth study, average values) than to those of the other methods.

but, on the basis of the cases tested, it was less accurate than the other methods. However, the amounts of yearly growth which White described as occurring at the epiphyses did not show great variations from those observed in the authors' cases. The inaccuracy arises largely from the fact that relative skeletal maturity is not considered, and that the ages which White used as indicating the cessation of growth could not be corroborated.

If various modifications are made in the method described by White, a technique is evolved which, as applied to the authors' cases, was quite accurate. This may be called the "fixed increment-skeletal age" method. The value used in prediction represents fundamentally a product of a fixed increment of growth, assigned to the particular epiphysis under consideration, and the number of years of growth remaining.

All computations are made with a correction for skeletal age, the ages of fourteen years and three months for girls and sixteen years and three months for boys being used as the times when growth in the extremities terminates. The yearly increments used are the average amounts which were observed in normal lower extremities of boys and girls in this series during the years of active growth. These are 1.3 centimeters for the distal femoral epiphysis and 0.9 centimeter for the proximal tibial epiphysis, except during the last year of growth, when the amount is approximately half these figures. To allow for this reduced growth in the terminal period, the figures are adjusted, for purposes of computation, as though the full increment were followed for a period of one-half year less than the actual period of growth. The effect of an arrest at a given age may then be approximated

by subtracting the age of the individual under consideration from thirteen and three-quarters years for girls and from fifteen and three-quarters years for boys, in order to obtain the number of years of growth on the basis of the full yearly increment. The figure so obtained is multiplied by the average increment of growth for the particular bone. In a boy ten and three-quarters years of age, for example, the formula for the effect of a femoral arrest would be as follows: $1.3 \times (15\frac{3}{4} - 10\frac{3}{4}) = 6.5$ centimeters.

To determine the indicated age for an arrest in a particular individual, one takes the amount of shortening in centimeters, divides this figure by the yearly increment of the femur (1.3), the tibia (0.9), or the combination of the two (2.2), as indicated, to ascertain the number of years required for the equalization. This figure is then subtracted from the age of thirteen and three-quarters years in girls or fifteen and three-quarters years in boys, to determine the age at which the arrest is indicated. The method has various defects, chief of which is that not enough data have been collected to indicate the range of individual variation in increments. It was, however, the second most accurate method when applied to the cases in this series, and does allow a prediction when no chart is available.

TABLE III

FINAL RESULTS COMPARED WITH THE PREDICTED EFFECT

	No. of Arrests	Per Cent.
Result within one-half inch of predicted amount	54	88.5
Result one-half inch or more above average prediction	1	1.7
Result one-half inch or more below average prediction	6	9.8
Delayed operative effect	4	
Other (one case)	2	
Total arrests with adequate measurements	61	100.0

The chart (Fig. 2) provided the most accurate prediction for the forty-one cases of arrest in this series which were available for the test (Fig. 4). It may be well to comment again that these cases were not included in the construction of the original table. In none of the uncomplicated cases in the test series did the outcome vary as much as 1.2 centimeters (one-half inch) from the average value predicted; in a larger group, to be discussed later, however, there were six individuals in whom a greater deviation occurred.

This chart has the advantage of providing a single graph which may be used directly, without mathematical computation. Moreover, it provides a range within which an individual may be placed, after consideration has been given to the various factors which might modify the expected amount of correction.

RESULTS OF EPIPHYSEAL ARRESTS

The clinical results of epiphyseal arrest in cases of infantile paralysis were evaluated in all patients in whom growth was complete and in whom observations existed before and after operation. Falling into this category were seventy-seven arrests, representing fifty cases; forty-one of the seventy-seven were in the test group discussed previously. The operations did not follow a constant technique, and the procedures were carried out by many different surgeons. Thirteen of the operations were done at other hospitals. All of the patients were available for evaluation of deformities and complications; in sixteen arrests, however, the measurements were inadequate to compare the amount of correction obtained with the result which had been predicted. These were mainly the cases in which teleoroentgenograms had been used for the early measurements.

CASES NOT QUALIFYING FOR THE TEST GROUP

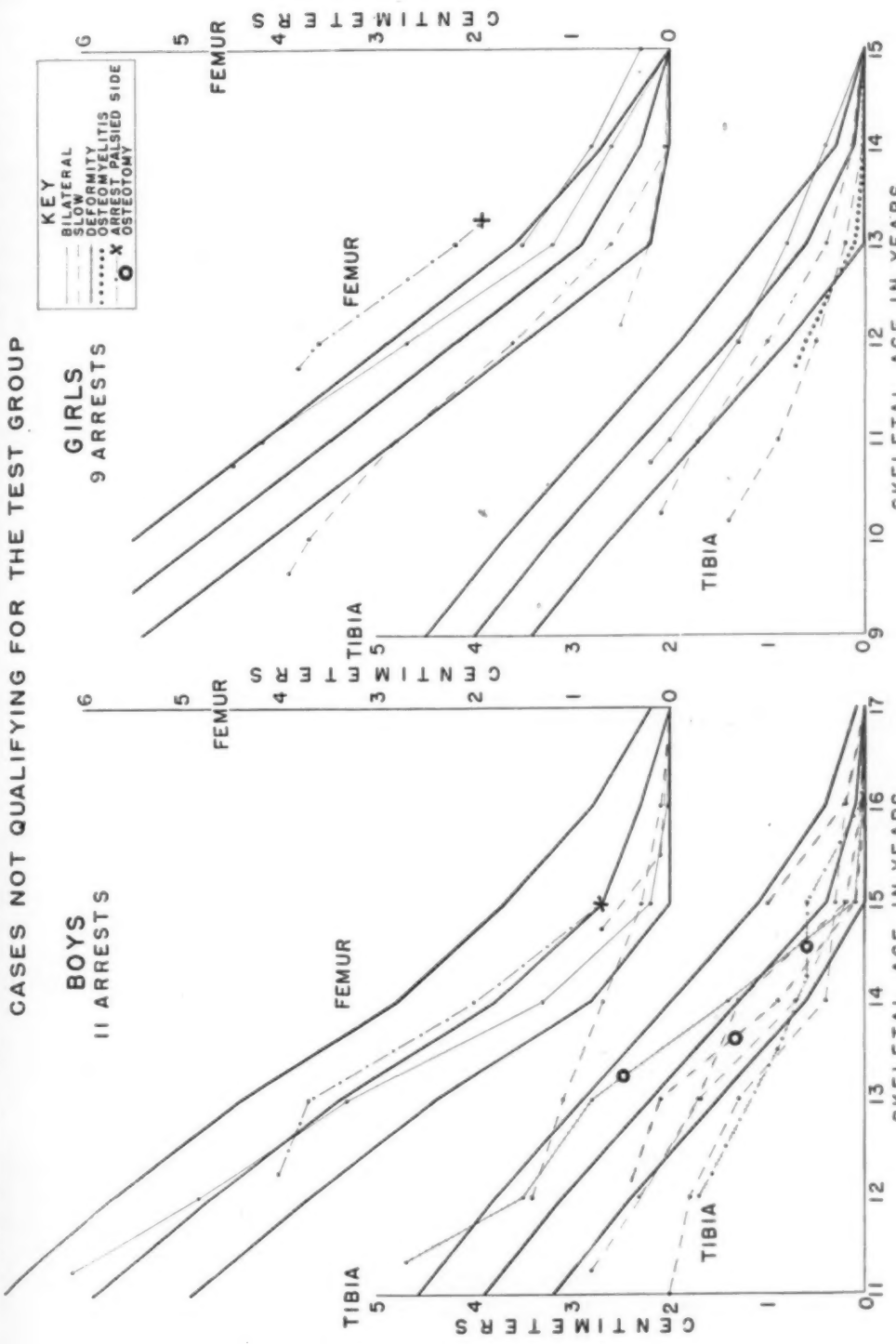

Fig. 5

The results of these twenty arrests could be measured adequately, but could not be used to test the methods of prediction because, for the various reasons indicated, they comprised an abnormal series.

CORRECTION OBTAINED

Not all cases adhered as closely to the prediction graph as did those used in the evaluation of the method. Of the sixty-one arrests which could be evaluated, the result was below the range predicted in ten; and in five the result obtained was above the range of prediction (Fig. 5). However, the discrepancy was small in most of these. In only seven arrests, represented by six cases, was the deviation as much as 1.2 centimeters from the average prediction; in six of these, the correction was less than that predicted; in one, the correction was 1.3 centimeters greater than the average prediction (Table III). The six arrests in which the result was less than that predicted showed a mean discrepancy from the average prediction curve of 1.8 centimeters, although one arrest which was technically ineffective deviated by 3.3 centimeters.

Deviations from the estimated amount seemed to be due primarily to two causes,—either an arrest which was not immediately effective on a technical basis, or an individual with marked irregularity of maturation, as judged by skeletal age. Secondary considerations were a patient with either very short extremities and a small increment of growth, or very long extremities and a very large increment of growth; and an arrest in a patient who showed marked inhibition of growth in a paralyzed extremity.

In four of the six arrests in which the correction was significantly less than had been predicted, the procedure was not effective for quite a long time after the operation. Examination of serial roentgenograms showed that these epiphyses remained open for a longer interval than normal. The slowness of the effect could be traced more or less directly to the operative technique, including instances in which bone grafts were inserted without drilling or curettage of the epiphyseal line.

For example, one boy had a tibial arrest performed at a skeletal age of eleven years, in order to equalize a two-inch discrepancy. The average predicted effect was 3.9 centimeters, with a possible range on the chart of from 3.2 to 4.6 centimeters. However, the epiphyseal line remained open for an abnormally long time, and did not become fused until two years after the operation. The growth of the arrested tibia was inhibited only

FIG. 6-A FIG. 6-B FIG 6-C

Fig. 6-A: W. B. had a tibial arrest at a skeletal age of twelve years and three months; genu valgum

developed, requiring osteotomy. Roentgenogram, taken one month after arrest, shows the tibial epiphyseal line to be open only on the medial side.

Fig. 6-B: Roentgenogram, taken twelve months after the arrest, shows marked genu valgum.

Fig. 6-C: Shows correction after osteotomy.

Fig. 6-D: Preoperative photograph shows the two-inch shortening.

Fig. 6-E: The degree of knock-knee prior to osteotomy is shown.

Fig. 6-F: Photograph after osteotomy shows the good contour of the extremity. The final correction in discrepancy amounted to 3.4 centimeters.

FIG. 6-D

FIG. 6-E

FIG. 6-F

26 per cent. during this period, instead of an average of 46 per cent.; and a femoral arrest was necessary. The total correction from the tibial arrest was only 1.9 centimeters; but the extremities were of equal length at maturity, because the femoral arrest was normally effective.

Two other arrests which were slow occurred in one patient, a girl, and were very unusual. The tibial arrest was performed at the age of ten years, and the femoral arrest at twelve years of age. The skeletal age was normal at these times. Both epiphyses closed promptly. The coefficient of inhibited growth in the paralyzed extremity prior to operation was only 14 per cent., which is close to the average figure for this series of cases; yet the result obtained in this patient showed the greatest deviation from the predicted result. She was a very short girl at all ages; her height was just above the tenth percentile*; and the tibia on the paralyzed side grew only 4.4 centimeters after the tibial arrest rather than the average increment of 6.7 centimeters. The effect was further reduced by the fact that the percentage of growth inhibited by the procedure was less than it should have been. A full explanation of the slowness was not apparent. In part, it occurred because of her short stature and lack of growth and because of an increase in the velocity of maturation after the arrest, but some other factor contributed to the unusual result. It seems likely that, for some unknown reason, there was an increase in the coefficient of inhibited

*See footnote to Table I.

TABLE IV

COMPLICATIONS FOLLOWING EPIPHYSEAL ARRESTS

	No. of Arrests	Per Cent.
Total arrests (50 cases with growth complete)	77	100.0
Tibia	43	
Femur	34	
Deformities (all in tibia)	5	6.5
Valgus	4	
Varus with genu recurvatum	1	
Osteomyelitis	1	1.3
Peroneal palsy (temporary)	1	1.3
Overcorrection of discrepancy	3	3.9

growth on the paralyzed side after operation. The interpretation was complicated by the fact that the patient had had a lumbar sympathectomy on the side of the short limb.

A patient who obtained more than the average predicted correction illustrates certain difficulties. Arrests of the upper tibial and fibular epiphyses were performed on a girl at the age of eleven years and three months, and a femoral arrest was carried out at the age of twelve years. Her skeletal age at these times was normal. The average predicted result for the two procedures was 4.3 centimeters, and the maximum was 5.6 centimeters. There was no reason to anticipate a deviation from the average prediction, since the patient was a child of average height and with only moderate involvement of the weak limb. After the arrests, however, she exhibited slowing of maturation, as judged by roentgenograms of her wrist; so that she grew for a longer period than was anticipated, and her shortening threatened to become overcorrected. A femoral arrest was performed on the paralyzed extremity at the age of thirteen, to make sure that the overcorrection would not be excessive. Examination, after growth was complete, showed that the bones of the extremity with the residual paralysis were 1.2 centimeters longer than those on the other side; but her limb lengths to the sole were equal, and her balance was symmetrical.

In two other cases the discrepancies were overcorrected, and in one a femoral arrest was performed on the opposite side to prevent further increase in length; however, the correction obtained in both instances was close to that predicted by the chart, and the error arose from choosing too early an age for operation (Table IV).

DEFORMITIES

Deformities following epiphyseal arrest have been reported by others. Straub, Thompson, and Wilson reported that, in 10 per cent. of their cases, deformities developed which were severe enough to require corrective operations. Regan and Chatterton described significant deformities in 11 per cent. of their patients.

In this series, five instances of deformities were observed in seventy-seven operations, and all followed tibiofibular arrests (Table IV). A valgus deformity was present in four; the other showed varus with associated genu recurvatum. Three of these patients have had osteotomies to correct the abnormality; following these, the final result was evaluated as good. In one, an osteotomy has been recommended; and in the other, the deformity is so slight that it does not warrant correction (Table V).

One of these patients (W.B.) showed almost immediate postoperative evidence of a developing deformity, because the operation for technical reasons failed to stop growth on the medial side (Figs. 6-A to 6-F, inclusive). A rearrest should have been performed before the deformity had progressed to the stage at which an osteotomy was needed. However, this boy exhibited increasing deformity for eighteen months, at which time a

TABLE V

SECONDARY OPERATIONS AFTER SEVENTY-SEVEN ARRESTS

	No.	Per Cent.
For deformities:		
Osteotomy	4	5.2
Done	3	
Advised	1	
Secondary arrest	1	1.3
For overcorrection:		
Femoral arrest in paralyzed lower extremity	2	2.6

wedge osteotomy was performed to correct the genu valgum. Following this, no further increase in the deformity occurred, and the final result was a limb of good contour with very little discrepancy in length.

In an analysis of the causes of deformity and the delay in effect of the arrest, the postoperative roentgenograms usually are a clue to the difficulty. Persistent asymmetry in the width of the epiphyseal line or failure of the line to become narrow and finally obliterated within a year are the important findings. If increments of growth are measured accurately and the correction does not follow the predicted pattern, one may suspect that the procedure has not been adequate. It is our custom, at this time, to insert a very small square of tantalum on the diaphyseal side of the plate, both medially and laterally. These squares, when visualized in serial roentgenograms, permit an accurate evaluation of the effectiveness and symmetry of the arrest. Roentgenograms of the area should be taken every three months until the epiphysis at the site of arrest has been completely obliterated. Careful clinical examinations should be performed at regular intervals, during the same period, to record any tendency toward deformity.

The technique of the operation seems to be the largest factor in determining the effectiveness of the procedure and the incidence of deformities. Certain of the surgeons carrying out the procedure in this series have had no cases in which deformities developed, and all of their arrests have been effective immediately.

TECHNIQUE OF OPERATION

The operative technique will be discussed only in so far as it affects the results of the procedure. The technique which is recommended includes a wide, thick graft on each side —ordinarily from seven-eighths of an inch to one inch (from 2 to 2.5 centimeters) in width— which should go well beyond the epiphyseal plate into the epiphysis, yet have a much longer portion on the diaphyseal side. It should extend at least one inch into the diaphysis so that, when the graft is reversed, the cartilage in the transplanted bone is well removed from its original position. In depth at the epiphyseal plate, the graft should be at least three-quarters of an inch (2 centimeters). The exposure of the epiphysis can often be facilitated by adding a transverse cut to the longitudinal incision in the periosteum. The operative sites should be located equidistant from the anterior and posterior surfaces of the bone; this will place the grafts in exact mid-lateral and mid-medial positions. The epiphyseal plate is drilled carefully throughout its extent with a hand drill, entry being made through the site from which the graft has been removed. The first drill point used is one-eighth of an inch in diameter, so that the cartilage may be followed accurately, by palpation with the drill point, as the drilling is performed. After this, drill points three-sixteenths of an inch and one-quarter inch in diameter are used, so that the epiphyseal plate will be thoroughly obliterated. Slivers of cancellous bone, pried from the bed of the graft in its extent in the

diaphysis, are then inserted into the obliterated plate so as to fill it in as completely as possible. Particular care is observed, when drilling the femoral epiphysis in the direction of the patellar groove and when drilling both bones directly posteriorly, not to go beyond the confines of the bone; the drilling of the posterior portion, however, should be thorough. The graft is rotated 180 degrees and reinserted so that cortical bone impinges upon cortical bone, with the graft fitting snugly and smoothly. This fit is facilitated by the use of matched osteotomes in pairs, when the graft is removed. The periosteum is reconstructed.

If this technique is followed carefully, postoperative deformity should be minimum, and arrest should be effective from the start.

COMMENT

It is well to recall that absolute equalization of length is not the goal in all cases. A patient who must wear a long brace with a locked knee joint, for example, is usually better with one or two centimeters of shortening on the side of the brace. Each problem should be considered individually.

For those who do not need a long brace, it is desirable for the extremities to approach equality of length. Procedures to correct discrepancy are particularly indicated when marked shortening exists in patients who do not require a brace.

To determine the degree of correction which is needed, the amount of lift required to restore balance in the standing position is the important consideration, and should be evaluated. Roentgenographic measurement of the bones and clinical measurements from the anterior superior spine of the ilium to the medial malleolus and to the sole should be recorded. The decision as to the amount of arrest needed arises from a combination of these evaluations. If a triple arthrodesis is planned for a later date, it is well to add one centimeter to the amount which is considered necessary, since this operative procedure reduces the height of the foot.

In planning the correction of a discrepancy of considerable degree, it is well not to wait until the age at which arrests of both the femoral and tibial epiphyses are indicated, but to perform one operation at a younger age and the other at the age when it is needed to complete the equalization. In this way less error will occur if, for some reason, such as a change in the pattern of maturation, the original prediction should not be accurate. Marked shortening of the leg (tibia) in girls is not desirable cosmetically.

In following the condition of patients who have asymmetrical involvement of the lower extremities, caused by infantile paralysis, not only the discrepancy, but the actual lengths of the extremities should be recorded at regular intervals. Highly desirable, but not essential, are accurate roentgenographic measurements at yearly intervals. Such information permits a calculation of the percentage of inhibited growth, as well as a record of the shortening and the length of the extremities. At intervals of a year or six months, roentgenograms of the wrist for evaluation of skeletal maturity are desirable. The evaluation of skeletal age by a single determination is very much less reliable than by serial examinations.

Finally, it must be stated again that the chart which has been presented is a tentative guide for the estimation of the effect of epiphyseal arrest, and not an absolute index. The irregularity of patterns of growth must be appreciated and considered as a limiting factor in any method.

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DISCUSSION

Dr. Frederic C. Bost, San Francisco, California: Since the origination of epiphyseal arrest by Dr. Phemister, other methods of equalizing leg lengths have rarely been necessary. The use of epiphyseal arrest requires exact information regarding the growth of bone. Quite accurate information concerning the growth of bone was adduced by Hatcher, by Gill and Abbott, and by J. Warren White. All of them used information obtained from records made by other observers who were concerned with the general growth of the child, and information obtained by anthropological studies. It is interesting that these methods of estimation should prove so nearly correct, as Dr. Green has pointed out in his present paper.

Dr. Green is the first to give us very accurate information concerning the growth of bone. These data he has obtained by serial roentgenograms made at half-year or yearly intervals. From the information which he obtained, he has presented a simple chart which shows the average growth to be expected at any given age. This chart is sufficiently accurate to be of practical use in treating patients who have inequality in lengths of the lower extremities.

Dr. Green's statistics are based upon measurements obtained from a large number of children, but much more information must be adduced before the measurements may be considered infallible. While exact equality of lengths is not essential for a good clinical result, nonetheless we should all collect further information concerning bone growth in order that greater accuracy may be possible. Dr. Green's measurements were made from orthoroentgenograms, a measurement which he described in an earlier paper. Scanography, described by Millwee and also by Gill, would seem to be an even more accurate method for measuring actual bone length.

Dr. J. Warren White, Greenville, South Carolina: I want to express my appreciation for these papers, which are a real help to those of us who are intensely interested in this subject. I would like to ask Dr. Green, who persuaded me eight months ago to take cognizance of bone age, about the determination of this important figure. In every roentgenogram we have taken, we have had trouble making this determination. I hope that something will be published soon which will be more accurate than the Todd method. We recently have been in communication with Dr. Bayley of the University of California, and she has sent information which has been of considerable value. I wonder if Dr. Green can give us some information by which we can more accurately interpret the bone age.

Dr. W. T. Green, Boston, Massachusetts (closing): As regards Dr. Bost's comment concerning the accuracy of the roentgenographic method, I should like to say that the method is accurate, as the determination depends upon focusing the tube consecutively over each joint, and hence upon the interception of the ends of each bone by parallel rays. This avoids magnification. The point of focus is recorded on the film by a marker in every instance, thus allowing us to check the technical accuracy of each film.

We shall always have some difficulty in predicting the effect of an arrest until we understand better the patterns of skeletal maturation, and are able to judge skeletal maturity more accurately. In 88 per cent.

(*Continued on page 678*)

THE POSTEROLATERAL APPROACH TO THE FEMUR

BY MAJOR GEORGE H. MARCY

Medical Corps, Army of the United States

From the Orthopaedic Service of the Twenty-third United States Army General Hospital

Reparative surgery of battle fractures has proved the value of the posterolateral approach to the femur. This approach was employed originally at the suggestion of Major Champ Lyons, in order to establish adequate dependent surgical drainage of the hematoma and of the infection complicating the femoral fracture, while the patient was on his back in traction and penicillin therapy was being used. The true posterior incision was considered to be contra-indicated, because of the possibility that sinuses, forming in the wound of incision, might result in involvement of the sciatic nerve.[1] The posterolateral incision was also indicated, whenever possible, in the débridement of wounds associated with fractures of the femur, in order to allow dependent drainage while the patient was being transported in a plaster spica from the Evacuation Hospital to the Base Hospital. Because of its many advantages and because of the fact that reduction and internal fixation could be accomplished easily and rapidly by a surgeon with the assistance of only one nurse, it soon became the incision of choice in both compound and simple fractures.

OPERATION

Position of the Patient: In the author's experience, the most satisfactory position for the patient is on the back with the lower extremity suspended by a Kirschner wire in the position of 90–90–90 traction, as described by Obletz, to a frame designed by Godfrey[3]. By this means, traction of the femur and reduction of the fracture are easily accomplished, with little exertion on the part of the surgeon or his assistants. The position relaxes the hamstring muscles by flexion of the knee, and also relaxes the sartorius and rectus femoris by flexion of the hip. Moreover, the upper end of the femur is brought down from beneath the glutaeus maximus by flexion of the hip, giving more extensive exposure. If such suspension is not possible, however, the patient may be turned slightly on the unaffected side or, easier still, placed on the abdomen with the limb draped so as to allow flexion of the knee.

Incision: The line of incision is from a point just proximal to the gluteal fold, halfway between the greater trochanter of the femur and the tuberosity of the ischium, to a point just proximal to the lateral condyle of the femur, between the tendon of the biceps femoris and the iliotibial band (Fig. 1). Along this line the sulcus between the biceps femoris and the vastus lateralis can easily be palpated, so that there need be no doubt as to the exact location of the incision. Any part of this line, or all of it, may be used for the incision, depending upon the exposure required. After the superficial vessels have been ligated, the deep fascia is sharply incised. The vastus lateralis is then bluntly separated from the biceps femoris along the fascial plane. In the middle third of the thigh, some care must be taken not to separate the long head of the biceps femoris from the short head of this muscle, which brings one in close proximity to the sciatic nerve and directly over the profunda artery and vein (see *Middle Thigh*, Fig. 1). In the middle third of the thigh, the second perforating branches of the profunda femoris artery and vein are encountered, passing transversely from the biceps femoris to the vastus lateralis. These may be retracted or, if necessary, divided and ligated. As the femur is approached, it is necessary to divide the thin origin of the vastus lateralis from the linea aspera. This is the only muscle cutting necessitated by the approach, and it is seldom associated with any bleeding. The femur and the fracture site are then exposed by incising and elevating the periosteum. After the

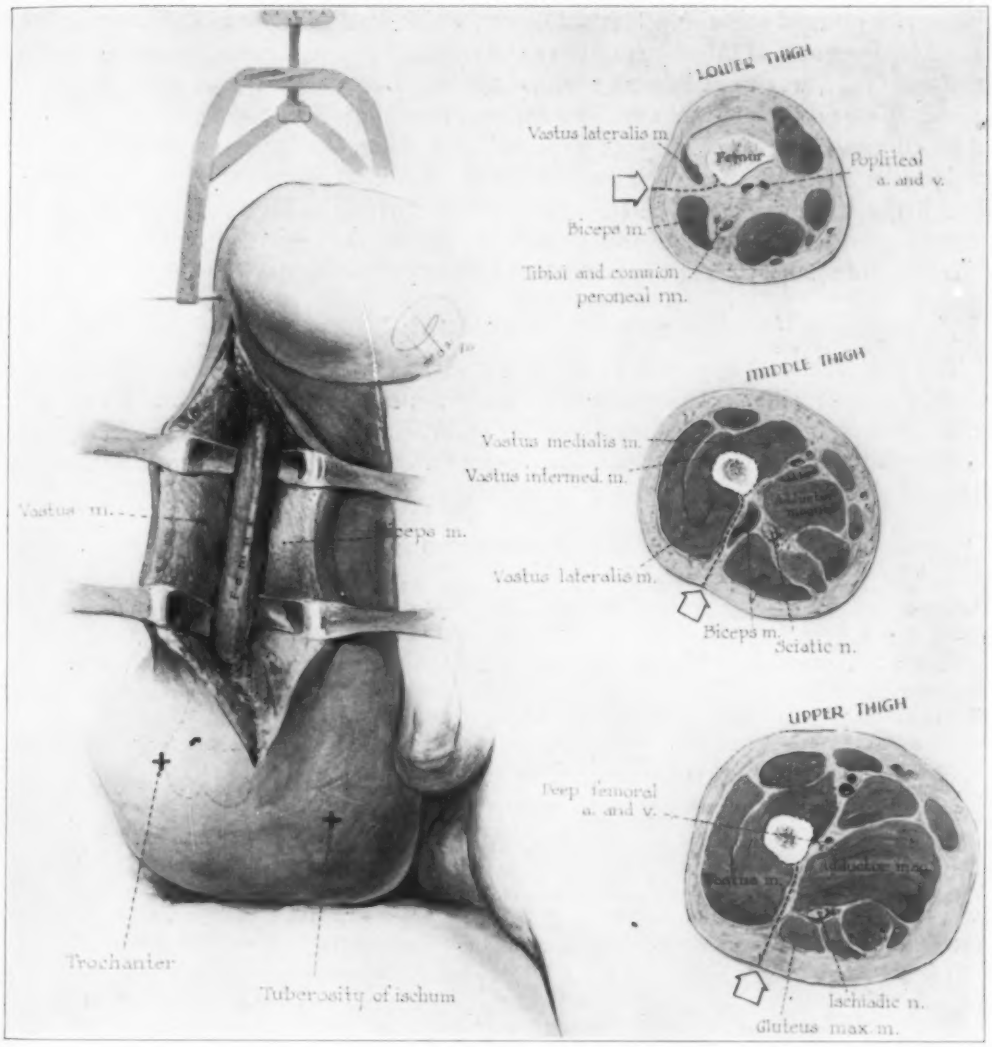

FIG. 1

surgery upon the femur, the incision may be packed open; or it may be partly or completely closed. The muscles fall together after the retractors have been removed, so that only skin closure is necessary. The fascia will repair itself.

In the experience of the Orthopaedic Service of the Twenty-third United States Army General Hospital, in treating 221 compound battle fractures of the femur[2], the incision was utilized either initially at the Forward Hospital or the Evacuation Hospital, or during reparative surgery in ninety-three cases. It was found that the approach gave easy access to the entire shaft of the femur. In several cases, the wound was so extensive, from the gluteal fold to the femoral condyle, that the entire shaft was exposed at once. Profuse bleeding, which is prevalent with the anterolateral incision, was never encountered, as only minimum division of muscles was necessary. The first, second, and third perforating branches of the profunda femoris artery were easily clamped and tied as they passed from the short head of the biceps femoris to the vastus lateralis.

When internal fixation was done, reduction and alignment were facilitated by the presence of the linea aspera and the flat surface of the femur, so that one plate with a transfixion screw, as recommended by Murray, or two plates at right angles, could be used. Adequate posterior dependent drainage of the fracture site was usually established, except

in cases with marked soft-tissue loss anteriorly, which made closure of the anterior wound impossible. Drainage of infections of the anterior quadrants of the thigh, especially of the medial quadrant, was unsatisfactory when this incision was used; and other means were required. After operation, the muscles were found to fall back together, as did the skin, so that small non-disabling scars were obtained even when the incisions were not sutured. Muscle scars or adhesions which limited the motion of the knee were not encountered, although the cases could not be followed sufficiently long to be certain of this. Sensory changes were minimum, as the incision lies between the skin areas supplied by the lateral femoral cutaneous nerve and the posterior femoral cutaneous nerve.

SUMMARY

The posterolateral approach to the femur gives easy anatomical access to the entire shaft of the bone with negligible blood loss, minimum muscle damage, and only slight, if any, circulatory or sensory impairment. It facilitates reduction, alignment, and fixation of the fracture, and allows for dependent drainage. The scar resulting from the incision is neither disabling nor disfiguring.

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DISCUSSION

WILLIAM T. GREEN AND MARGARET ANDERSON

(*Continued from page 675*)

of the whole group, however, the effect from epiphyseal arrest, performed by many different surgeons in the hospital, was within one-half inch of the prediction. Most of the variations from the predicted effect were traced to the technique of the operation.

The details of the operative technique are most important, and the reason that many are critical of the procedure is that the operation is not performed satisfactorily. A poor arrest may not obtain the predicted effect because it does not slow down growth immediately; an arrest which is done poorly on one side will produce deformity. I think that epiphyseal arrest is a good procedure, and that it is the best way to equalize the length of the extremities of the growing child in most instances.

As regards Dr. White's question, I think we should appreciate that accuracy in prediction of skeletal maturity is essential, and that we still have difficulty with it. Particularly do we have trouble with those unusual children who show variations in their patterns of maturation. For example, a child may seem by roentgenographic evaluation to be retarded in skeletal maturation at a particular period, but subsequently he shows very rapid maturation, which changes the relative position of the skeletal to the chronological age. This child, therefore, grows for a shorter period than was anticipated, and thus the effect of an arrest will be less than that predicted. Problems likewise arise with those who seem to mark time in their skeletal maturation, with the result that they grow for a longer period than was anticipated. We hope to know more about this irregularity in the velocity of maturation as time goes on.

KNEE MOVEMENT FOLLOWING FRACTURES OF THE FEMORAL SHAFT *

BY JOHN CHARNLEY, F.R.C.S., MANCHESTER, ENGLAND

In this paper an attempt has been made, by clinical inference, to examine the subject of knee stiffness following a fracture of the shaft of the femur.

In the past, it has been customary to regard the maintenance of knee movement after a fracture of the femur as a simple mechanical problem. Evidence suggests, however, that knee motion after such a fracture depends only in part upon simple mechanical factors; and that the key to *perfect* joint function will be found only when the key to *early* bony union has been discovered.

A mechanical barrier to knee motion following a fracture of the shaft of the femur can involve three structures,—the articular surfaces of the joint, the capsule of the joint, and the extensor apparatus of the thigh (Fig. 1). In a severe case of long duration, probably all three sites may be involved simultaneously.

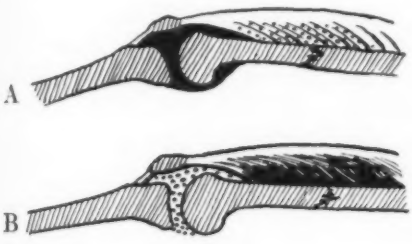

FIG. 1

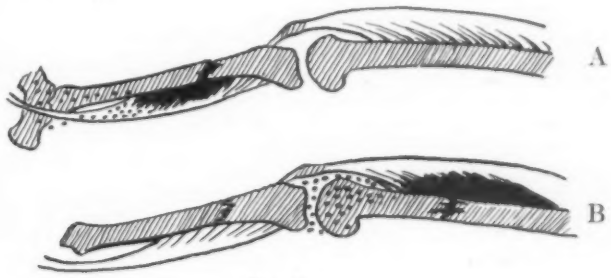

FIG. 2

Fig. 1: Showing mechanical barriers to knee motion.

A: Illustrates the orthodox conception of the usual cause of intractable knee stiffness after a fracture of the femur. Extra-articular adhesions are known to exist, but are regarded as of secondary importance.

B: Illustrates the author's conception that the "master adhesions" lie in the quadriceps and that the intra-articular adhesions are secondary, both in development and in importance.

Fig. 2: Illustrating the difference in knee stiffness after fractures of the fibula and tibia in comparison with fractures of the femur.

A: After six months' fixation for a fractured tibia, no stiffness of the knee results.

B: After fracture of the femur, the knee may be very slow to recover movement, if it has been fixed in plaster for three or four months. This is not so much the effect of the fixation on the knee as the result of fibrosis in the quadriceps which, in turn, is dependent upon the biological conditions for bony union of the fracture.

EVIDENCE FOR EXTRA-ARTICULAR ADHESIONS

The following evidence is given in favor of the theory that limitation of knee motion following a fracture of the femur is caused by extra-articular forces.

1. Comparison with Fractures of the Tibia and of the Fibula

In the treatment of fractures of the tibia and the fibula, it is not uncommon to fix the knee in plaster for six months or more, and yet little or no difficulty is experienced in achieving 90 degrees of motion at the end of a few weeks, and even full range is often secured within the same length of time.

It is possible to explain this difference in behavior in the knee joint, because in the case of the femur there might be involvement of the quadriceps femoris in scar tissue, whereas in a fracture of the tibia the quadriceps femoris is not involved (Fig. 2).

2. Injuries of the Knee Joint Unaccompanied by Fracture of the Femur

When immobilization in plaster is used for three or four months, the recovery of knee mobility after severe injuries to the ligaments of the knee is often astonishing. Sir Robert Jones has commented upon the good knee motion which is usually attained in cases of

* Based on a Hunterian Lecture delivered at the Royal College of Surgeons, May 23, 1946.

complete dislocation of the knee, when immobilization in plaster is used as treatment: "The interesting fact is that, in spite of the extensive rupture of ligaments, including the crucial ligaments, the functional results in recorded cases have been so good. The explanation of this is that the lesion is so formidable that prolonged fixation is absolutely necessary; early use and movement is impossible without displacement occurring. Hence torn structures are usually given time to unite firmly, and with exercise and use, considerable freedom of movement is recovered in time. . . . The great lesson seems to be that if the displacement is reduced and the limb fixed in a straight position, nature will do surprisingly well."

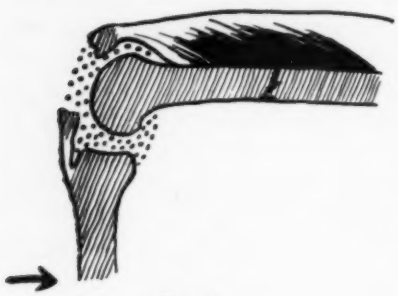

FIG. 3

Illustrating the significance of fracture of the patella, which may occur if violent flexion force is applied to a stiff knee after a fracture of the femur. The "master adhesions" in the extensor apparatus must offer greater resistance to flexion than the intra-articular adhesions, which are readily overcome, once the extensor expansion has ruptured.

3. Fracture of the Patella During Manipulation

In patients who have had fractured femora in the past, it is well known that the patella may be fractured by violent manipulation of the stiff knee. This would seem to indicate two facts,—first, the existence of "master adhesions" lying proximal to the patella, and, second, that the adhesions within the joint are less formidable, because they can be overcome with comparative ease once the knee has been disconnected from the thigh by the rupture of the extensor mechanism.

4. Results of Plastic Operations on the Quadriceps

Excellent results have been described following the excision of the adherent vastus intermedius described by Thompson. The operation offers a good possibility of securing 90 degrees of motion in knees which before operation were very stiff. The procedure is often combined with lateral and medial incisions of the capsule of the knee joint. After division of these extra-capsular structures, the knee can be flexed with the application of only moderate force, whereas before operation it may have resisted very powerful force.

5. Results of Plating Operations

In general, after internal fixation of fractures of the femur by means of metallic plates, prognosis for knee movement is not encouraging. Most surgeons attribute this to adherence of the quadriceps in the vicinity of the plate.

EVIDENCE FOR INTRA-ARTICULAR ADHESIONS

1. Direct Evidence at Operation

Arthrotomy is not often performed on stiff knees following old fractures of the femur, but it would appear, from discussion with surgeons who have had this opportunity, that intra-articular adhesions can be demonstrated. However, as already pointed out, it is possible that these intra-articular adhesions may be of secondary importance to more formidable adhesions already existing in the quadriceps.

2. Coincidental Injuries to the Knee

The knee joint often shows effusion following fracture of the femur. This is taken to indicate that the knee suffered injury at the same time as the femur; but, as already stated, even severe ligamentous injuries do not necessarily result in a stiff knee. Experimental work with animals does not suggest that intra-articular adhesions are common after prolonged fixation of normal joints [6].

CONSIDERATION OF EVIDENCE FOR THE CAUSES OF STIFFNESS IN THE KNEE

From this evidence, there would seem to be a stronger case for finding the primary site of adhesions in the vastus intermedius than within the knee joint.

It would seem reasonable, therefore, to suppose that intra-articular adhesions result from the prolonged fixation imposed by "master adhesions" within the quadriceps.

TABLE I

RANGE OF KNEE MOVEMENT AT SIX AND AT TWELVE MONTHS AFTER FRACTURE OF THE FEMUR IN RELATION TO CLINICAL UNION

Time of Union (*Weeks*)	Knee Range at Six Months (*Degrees*)	Knee Range at Twelve Months (*Degrees*)
Before Eight Weeks		
6	145	150
8	90	120
6	90	120
6	120	150
8	...	100
6	120	...
6	120	150
6	150	150
6	120	135
3	90	135
6	120	...
8*	...	135
7*	110	120
8*	110	120
6*	120	140
8*	...	120
8*	90	120
8*	...	120
8*	110	120
8*	120	120
Averages 6.8	114.1	129.1
After Eight Weeks		
14	30	90
16	90	120
12	90	135
32	...	120
10	90	90
20	...	80
24	...	120
12	...	150
10*	120	135
10*	90	90
13*	45	110
9*	120	135
16*	50	100
16*	20	...
Averages 15.3	74.5	113.5

* Denotes fractures which are open, but without bone sepsis after one month.

UNION AND RANGE OF MOTION

Of all the factors influencing the final range of motion of the knee after a fracture of the femur, speed of union is probably the most important. If union occurs quickly, the ultimate range of motion will be excellent, even if it has been necessary to keep the knee fixed throughout treatment.

The figures in Table I were obtained from a series of thirty-four fractures of the shaft of the femur. All of the patients selected were free from sepsis after four weeks, and were in the age group of twenty to forty-five years. Knee movement was not begun until clinical union could be detected. Those patients who showed clinical union at or before eight weeks

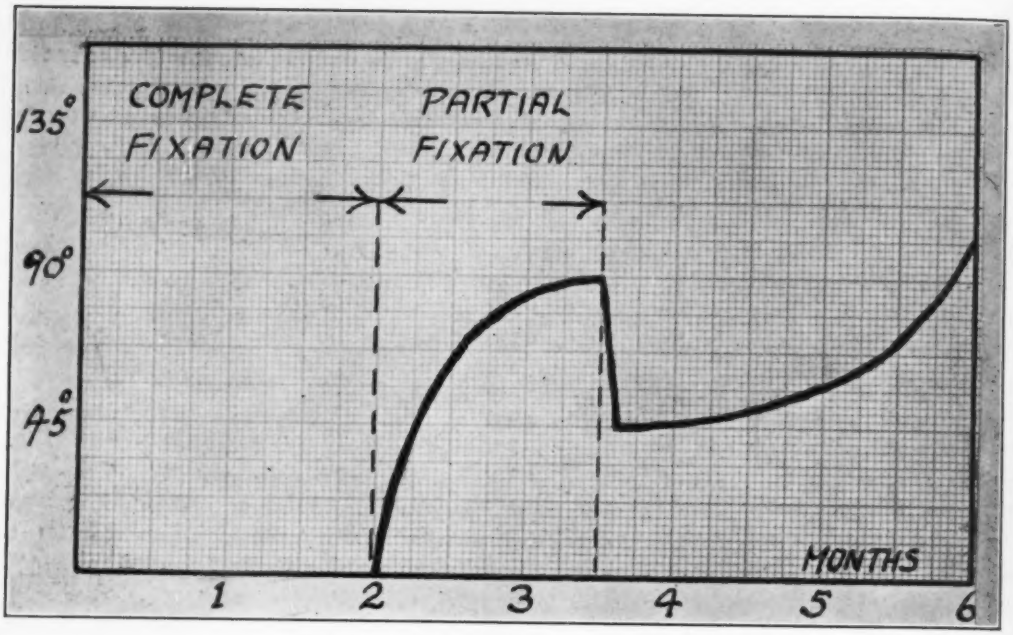

FIG. 4-A

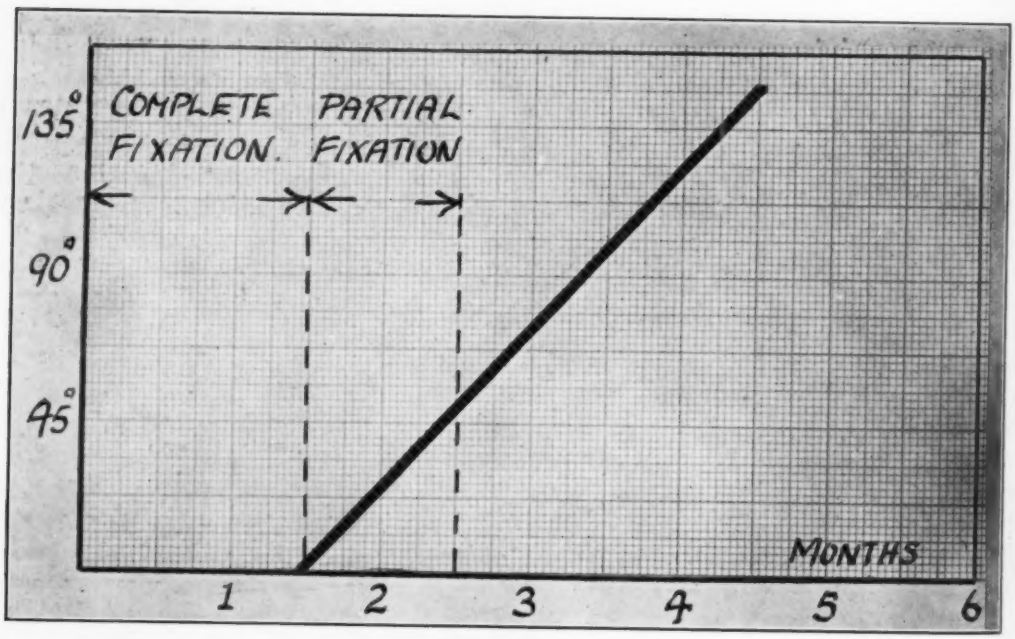

FIG. 4-B

In Fig. 4-A is seen the sudden deterioration of knee movement after the thirteenth week, when all external support had been discarded. This depressed range persisted for about one month before spontaneous recovery started. It is postulated that this spontaneous recovery was held in abeyance until true consolidation of the fracture had been assured, and that the return of knee movement was not a simple mechanical phenomenon, but was primarily dependent upon the state of the fracture.

In Fig. 4-B is illustrated a case in which strong bony union took place without incident and without any threat of re-fracture or late angulation. Knee movement returned spontaneously and progressively.

(average time was 6.8 weeks) had an average range of motion of 114.1 degrees, six months after fracture. Those patients who did not show clinical union until after eight weeks (average time was 15.3 weeks) had an average range of motion of 74.5 degrees six months after fracture (average difference was 39.6 degrees at six months). At one year after frac-

ture, the average ranges were respectively 129.1 degrees and 113.5 degrees (average difference was 15.6 degrees at twelve months).

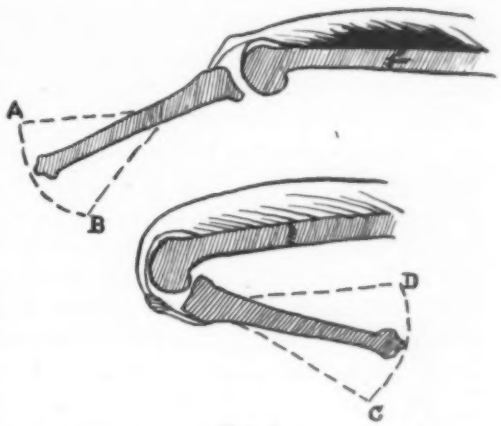

FIG. 5

Mechanical exercise over the arc *BA* at or before six weeks can have no direct influence on the final recovery of the range in the arc *DC* some six months later. Recovery of the range *DC* is dependent upon biological factors at the fracture site, which determine whether the provisional callus is absorbed completely or leaves permanent scar tissue in the muscle.

RANGE OF MOTION AND SOUNDNESS OF UNION

The existence of some relationship between sound union and recovery of knee motion is illustrated by the following experience.

It often happens that a patient with a fractured femur, who has been allowed early movement, may have attained a considerable range of motion in the knee by the end of three months, and by this time union may appear to be clinically firm. If the limb is then taken off traction and allowed to lie free in bed, it may happen that after a few days the range of motion will diminish very noticeably. This may occur in spite of the fact that repeated clinical tests have failed to reveal any of the ordinary signs of threatened angulation or re-fracture (such as the reappearance of tenderness over the callus or actual movement at the site of the fracture). This temporary loss of motion may persist for some weeks before the range of motion eventually equals, and later exceeds, that secured while the limb was in traction.

An example of such a result is demonstrated in Figure 4-A. The figures here were taken from an actual case. Knee movement was started at the end of the seventh week after fracture, the bone by that time being clinically solid at the fracture site. The range of motion of the knee increased rapidly at first until 90 degrees was reached. At this point, clinical union still seemed sound; indeed the patient regarded his splints as futile, and waved them around the bed by active contractions of the quadriceps. Splintage was removed; the next day the range of motion had fallen to 45 degrees. This lowered range persisted for about four weeks, although the limb was free to be exercised at all hours of the day, instead of at limited and prescribed periods under supervision, as had been the regimen before the splint was removed. After the range of motion had started to improve, 120 degrees was attained in six months.

It is this type of case which makes the critical observer wonder whether, in an exactly controlled series, any outstanding difference in the *ultimate* range of the knee would be revealed as the result of different forms of treatment. The common "hold-up", which is so often encountered at about the 90-degree range, tends to eliminate the difference in final results between cases in which motion was started early and those in which it was started late.*

RECOVERY OF COMPLETE RANGE IN FLEXION

The longer the knee joint is immobilized, the greater will be the permanent stiffness. On the other hand, very early movement does not guarantee full recovery of knee range.

In one case of a mid-shaft fracture of the femur, the knee was started on assisted movement at three weeks, in an experimental device permitting a free range of 90 degrees while on traction (a device which proved too elaborate for general routine use). The patient secured 90 degrees of motion at seven weeks. At the end of twelve weeks, his fracture had united, and the splints were abandoned. He secured no more than 90 degrees

* In judging this statement, the clinician must guard against an erroneous general impression from the results of early and late knee movement in an uncontrolled series. Only too often those cases which respond well to early knee movement are taken as examples of that method, and *those cases in which early movement has had to be abandoned for various complications are relegated to the class of late knee movement.*

at six months, and the range at twelve months was 135 degrees (the patient was of spare build, and full range was estimated at 150 degrees). The final range was good, but, although motion was started earliest in this series, final range was not so complete as in a number of other cases which were treated by much slower methods.

That the recovery of the last few degrees of full flexion is not dependent upon simple mechanical factors in early treatment would seem to be fairly obvious. The recovery of full range depends upon the complete absorption of all scar tissue in the region of the healing fracture. It is difficult to see how exercise of the knee, during the first three weeks, on a limited range centered on the semi-extended position, can have much direct influence on the return of the last few degrees in the position of full flexion some nine to twelve months later (Fig. 5). The production of minimum scar tissue around a fracture is dependent upon biological factors and not upon simple mechanical movement of the knee.

FINAL KNEE RANGE IN THE PRESENT SERIES

The thirty-four cases in this series were treated with fixed traction on a straight Thomas splint in accordance with the basic principles of Thomas, and as discussed in a previous paper [2]. The prolonged fixation of the knee, according to the classical method [3], was abandoned as soon as evidence of clinical union at the fracture site had been detected.

It is of interest to note, in view of the satisfactory range of final knee motion, that the exercises * for knee flexion, when first started at about the eighth week, rarely lasted for more than five or ten minutes twice a day. This tentative knee exercise was made a sideline to quadriceps drill, in the belief that static contraction of the quadriceps could free the muscle fibers from adhesion to the fracture site. These contractions affected the whole extensor apparatus, from the muscle fibers to the lateral expansions of the joint capsule.

The results of this series are indicated in Tables II and III. The average age of the patients was 26.5 years. Clinical union of the bone was detected, and motion of the knee was started at the average time of ten and one-quarter weeks. The average range of motion of the knee after twelve months was 121 degrees. In those cases in which the range of motion was known at six months after fracture (twenty-seven cases out of the thirty-four) there were twenty-three patients (85 per cent.) who had 90 degrees or more.

EARLY KNEE MOVEMENT AND FRACTURE UNION

It is one of the claims of those who believe in starting early motion of the knee after a fracture of the femur that union of the femur is thereby stimulated. It is certainly true that early union by this method is more obvious than in methods employing splints, because the limb can be readily tested for union day by day.

In Tables II and III, showing the cases in which *late* knee movement was allowed, it would be difficult to imagine that early movement could consistently produce clinical union at a significantly earlier time.

A HYPOTHESIS OF KNEE MOVEMENT

Sufficient evidence concerning the behavior of the knee after fractures of the shaft of the femur has been advanced in the preceding paragraphs to warrant the attempt to bring them together into a tentative hypothesis.

It would appear reasonable to suggest that the ultimate range of knee motion depends upon two factors: a *mechanical* factor related to mobilization by physical processes, and a *biological* factor relating to the amount of scar tissue produced in the quadriceps.

* The method used for knee mobilization was simple in the extreme, but needed the constant vigilance of the physiotherapist in attendance. The fixed traction cords of the Thomas splint were untied, all slings were removed from behind the leg distal to the knee, and, with the masseuse supporting the calf, the leg was gently lowered until the foot touched the bed. This movement was repeated slowly a few times, and then the traction cords were retied and the slings reapplied. As the range of flexion increased, the foot of the Thomas splint was raised. There would have been risk of lateral angulation developing by this technique, if the masseuse had not been trained in retying the traction cords and readjusting the splint at the end of each exercise.

TABLE II

KNEE RANGE IN NINETEEN CASES OF CLOSED FRACTURE

Patient	Age (*Years*)	Time in Fixation (*Weeks*)	Degrees of Knee Range		
			After 6 Months	After 12 Months	After 24 Months
C.	28	6	145	150	150
C.	26	8+6	30	90	...
C.	26	16	90	120	...
C.	28	7	120	...	...
D.	28	8	90	120	135
R. G.	28	6	90	...	120
L. G.	28	8+4	90	...	135
H.	24	6	120	150	150
J.	28	32	...	120	...
L.	20	10	90	90	120
M.	33	14+6	...	80	...
McL.	24	8	...	100	100
P.	41	6	120	...	...
R. S.	19	6	150	150	150
L. S.	19	6	150	150	150
S.	24	6	120	135	...
G. S.	20	3	90	...	135
U.	41	24	...	120	120
W.	37	8+4	120	150	150
Averages	27.5	11	108	123	135

TABLE III

KNEE RANGE IN FIFTEEN CASES OF COMPOUND FRACTURE WITHOUT SEPSIS

Patient	Age (*Years*)	Time in Fixation (*Weeks*)	Degrees of Knee Range		
			After 6 Months	After 12 Months	After 24 Months
B.	22	8	...	...	135
C.	34	7	110	120	...
C.	26	8	110	120	135
C.	21	6	120	140	140
D.	28	10	120	135	135
D.	23	10	90	90	90
H.	23	8	...	...	120
K.	28	8	90	...	120
P.	29	13	45	110	120
P.	20	5+4	120	135	...
R.	25	8	...	120	150
S.	32	16	50	100	100
S.	24	8	110	120	135
S.	22	16	20	...	100
T.	25	8	120	120	135
Averages	25.5	9.5	92	119	124

The mechanical factor is obvious. It is the freeing of muscle from involvement in callus by simple mechanical movement. Some other factor must be present in addition to the simple mechanical factor, however, because early knee motion does not always result in a perfect knee, and, on the other hand, late knee motion can often produce a mobile knee.

The biological factor governs the complete removal of the temporary tissues of repair. In some cases the temporary tissues of repair are converted into permanent fibrous scar tissue. Such a process causes tethering of the surrounding muscles. This almost invariably follows when there has been sepsis; but the healing of a closed fracture should leave no permanent scar tissue.

It has been the writer's constant observation that, when the femur reveals a noticeable absence of bony callus in the roentgenogram at about six weeks, there will always be a threat of limited knee motion, *even if the femur is being treated on an apparatus permitting knee exercise.* This observation is interpreted as indicating that the provisional callus, failing to become bony callus, is attempting to effect a union of the femur by permanent scar tissue and, in so doing, involves the adjacent muscles in the adhesive process. The production of large amounts of permanent scar tissue around closed fractures will only be explained when the intimate nature of delayed union is understood.

By contrast, it has been the constant observation of the writer that femora which show bony callus at from three to four weeks will unite early, and that eventually there will be perfect motion of the knee. Profuse bony callus appears to result in much less adhesion of the quadriceps than the radiotranslucent scar tissue, which presumably is present when bony callus is deficient.

When fibrous tissue is produced in the tissues surrounding a closed fracture, it is possible that the liberation of muscle fibers by mechanical movement is a futile hope. There is some collateral evidence to suggest that passive motion in these conditions may even be harmful. When myositis ossificans develops near a fracture site, it is well known that the best chance of securing a useful range of motion in the associated joint is by limitation of exercise. Passive movement in these cases can increase the area of the pathological process in the muscle fibers.

CONCLUSIONS

1. Evidence has been produced to show that adhesions in the quadriceps may be the primary cause of knee stiffness after fractures of the shaft of the femur.

2. The recovery of perfect knee movement after a fracture of the shaft of the femur depends upon the complete absorption of scar tissue involving muscle at the fracture site.

3. The production of scar tissue around a fracture and the involvement of the surrounding muscles is a biological process, related to the healing power of the fracture and unrelated to early mechanical knee motion.

4. If the fracture of the femur shows clinical union in eight weeks, final knee motion will be excellent even if the knee remains fixed throughout treatment. Scar tissue in these cases is minimum, and bony callus is plentiful.

5. If the fracture of the femur shows delayed union, it is doubtful whether mechanical knee movement will prevent considerable permanent knee stiffness. In these cases, bony callus is scanty, permanent scar tissue is plentiful, and quadriceps tethering occurs.

NOTE: The author takes pleasure in acknowledging his indebtedness to Professor Harry Platt for his constant encouragement and advice, particularly during the writing of this paper. He is also indebted to Professor S. L. Baker, Department of Pathology, University of Manchester, with whom discussions of the utmost value on the healing of fractures have been held.

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ARTHRODESIS OF THE HIP JOINT IN DEGENERATIVE ARTHRITIS

A Modified One-Stage Procedure with Internal Fixation

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The general consensus [3,4,6,8] among orthopaedic surgeons who have experimented with various surgical procedures for the relief of painful hip joints in degenerative arthritis is that arthrodesis is the most satisfactory method; but the operation has presented certain difficulties and hazards that have tended to limit its application in practice. During the past decade, there has been increasing interest in the surgical treatment of the hip, stimulated in large part by Smith-Petersen's work on acetabuloplasty and arthroplasty. This has furnished a valuable contribution in this field, and has yielded more flexibility in choice of procedures for surgical treatment; but it has also led to the realization that mobility of the joint does not always solve the problem or afford the patient the desired relief. When there is bilateral hip involvement, and in numerous other cases, maintenance or increase of motion may be desirable; but there remains a certain group of cases, particularly those with one painful hip resulting from degenerative arthritis, in which relief of pain is the prime or sole purpose of treatment, and this desired result can be achieved only by fixation of the hip joint in the best possible position for function. The technique described here has been developed especially for the management of such cases.

In addition to the fact that successful arthrodesis has not been obtained in all cases in which it has been attempted by other procedures, the main disadvantages of these operations have been: (1) The procedures have been formidable and time-consuming, often productive of severe surgical shock; (2) they have required long periods of immobilization in plaster casts, presenting the serious hazard of postoperative complications in the elderly patient; and (3) they have involved great financial expense.

Older methods [1,2] of hip fusion usually consisted in removal of cartilage and fibrous tissue from the joint; they required disarticulation, with insertion of some type of intra-articular or extra-articular graft, followed by external fixation in a plaster spica until fusion had been secured. When the joint cartilage was not removed, the hip was fused with a graft; and any deformity present was retained or had to be corrected by a secondary osteotomy. Although some orthopaedic surgeons [4,8] still use these methods, there has been increasing interest in the application of the principle of internal fixation, first made popular by Watson-Jones. He contended that the clue to successful fusion, after the joint has been denuded of cartilage, is control of rotary movement, a control which cannot be assured by the plaster spica, but which can be assured by a three-flanged nail driven from the femur into the pelvis. In addition, he applied a plaster spica, and kept the patient immobilized for three months. At first he performed the operation in one stage, but this proved too formidable, especially in elderly patients, so it was later done in two stages, with insertion of the nail and application of plaster ten to fourteen days after the intra-articular procedure.

The Watson-Jones operation has been advocated as the procedure of choice by Campbell and Haggart. Numerous modifications of this technique, using internal fixation with a metal nail, with or without additional bone grafts, and with or without disarticulation and removal of cartilage from the joint, have been advanced during the past few years by White, Harris, and Niebauer and King. In the authors' opinion, all of these different methods have certain advantages and disadvantages, but none quite overcomes the salient difficulties.

One of these difficulties is presented by removal of cartilage from the head of the femur and from the acetabulum to obtain contact of bone with bone. This reduces the size of the femoral head and increases the size of the acetabulum, often producing gross disproportion, which contributes to instability and rotary movement of the joint, and prevents its satisfactory fusion. When internal fixation is applied, however, without any intra-articular procedure, the joint may be fixed in malposition, perpetuating the deformity and requiring additional surgical treatment.

The authors have been attempting constantly to devise a procedure which would take account of the foregoing difficulties, and would fulfill other desiderata in connection with the relief of pain in the hip by arthrodesis. The following factors were considered important: (1) The operation should be performed in one stage, in order to reduce the surgical hazards and the expense to the patient. (2) The adduction and flexion deformities should be corrected before application of internal fixation. This should be done, if possible, without dislocation of the hip, in order to minimize shock. (3) The cartilage on the head of the femur and that lining the acetabulum should not be removed and discarded, since this leads to instability of the joint and delay in bridging of bone across the joint, despite the bone contact so produced. (4) Internal fixation with a nail should be used to avoid immobilization in plaster, and to lessen the risk of complications and the length of time spent in the hospital. (5) A graft should be used to increase stability and ensure fusion of the joint.

The following technique has been developed to satisfy these conditions. It combines the advantages and avoids the disadvantages of other procedures, and is productive of excellent clinical results.

TECHNIQUE

The hip joint is exposed by a Smith-Petersen incision. In the first operations performed with this technique, the distal end of the incision was extended laterally to allow exposure of the subtrochanteric region. This required considerable dissection of tissues, so that, in later cases, it has been found preferable to make a second small lateral incision for insertion of the nail.

With the special curved chisel devised for arthroplasty by Smith-Petersen, the fibrous union between the femoral head and the acetabulum is broken up and the cartilage on both surfaces of the joint is thoroughly laminated. This allows correction of adduction and flexion deformities, and roughens the cartilaginous surfaces. If the joint has been sufficiently freed by this method, it is possible to manipulate it without dislocation of the femoral head, so as to achieve the ideal position, which is flexion of 30 degrees, abduction of not more than 5 to 10 degrees, and slight external rotation (about 5 to 10 degrees).

The secondary incision is then made; and the femur is nailed to the ilium by means of a Vitallium or steel nail, about five and one-half or six inches long, under roentgenographic control. The nail is driven through the neck and head of the femur and deep into the expanded thick area of the ilium, over the superior roof of the acetabulum. As other authors [9] have noted, one may encounter difficulty in driving the nail into the sclerosed bone in the acetabulum. The procedure is facilitated if that portion of the bone is well laminated with the chisel at the time the femoral head is being freed from the acetabulum. The fact that the nail is hard to drive into the acetabulum makes the head and neck of the femur ride down on the nail during its insertion, so that special care should be taken to see that thorough impaction of the joint has been accomplished, before the nail is finally driven in. It has been found advantageous to tap the impactor and the nail alternately until the nail is finally placed.

A block of bone is removed from the anterolateral surface of the femoral neck and head and from the acetabular margin, forming a slot, into which a graft taken from the ilium is fitted like a key. The graft is then thoroughly impacted in its bed, and the proce-

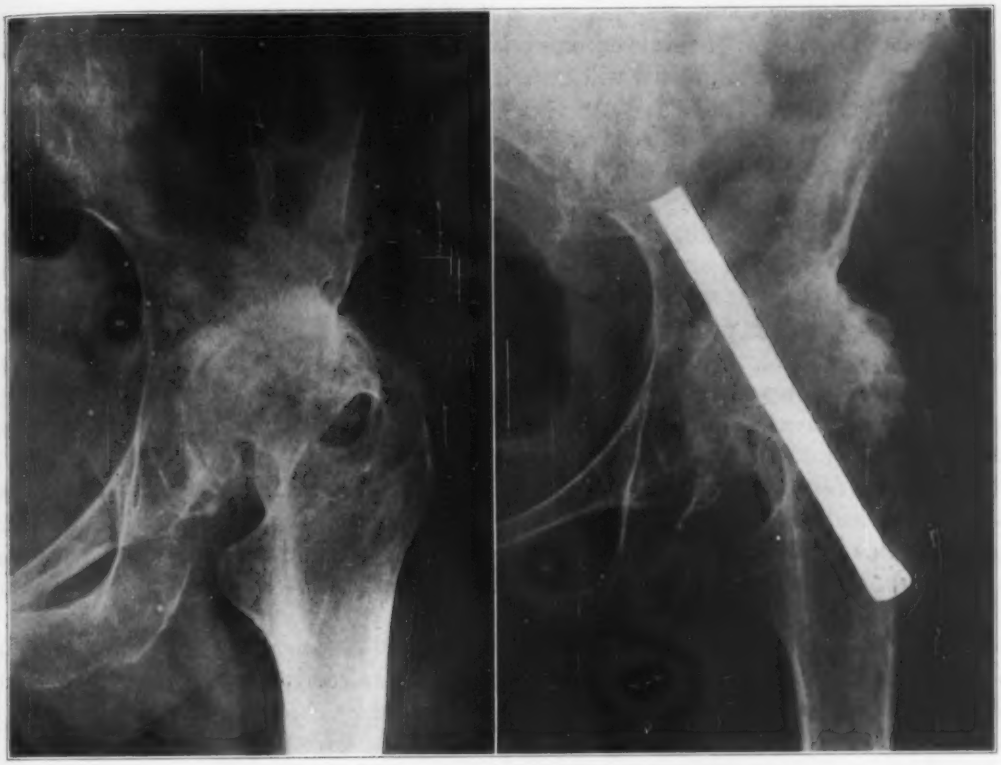

FIG. 1-A FIG. 1-B

Fig. 1-A: Case 2. Roentgenogram taken before operation shows pronounced arthritis of the left hip.
Fig. 1-B: Shows solid fusion of the left hip joint, five months after operation.

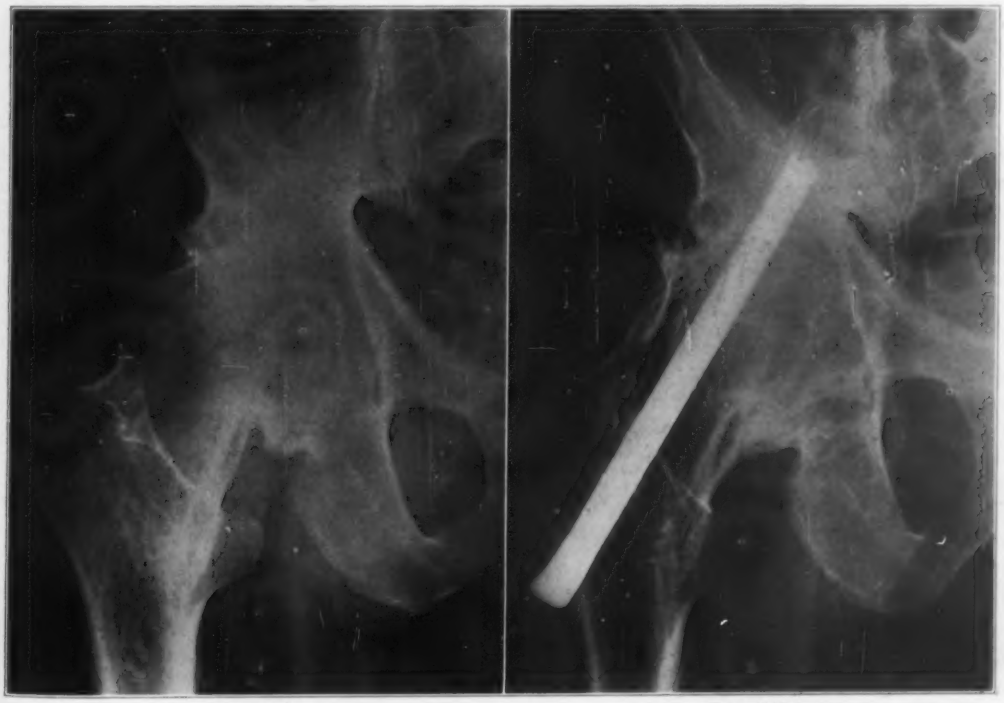

FIG. 2-A FIG. 2-B

Fig. 2-A: Case 4. Roentgenogram shows extensive hypertrophic arthritis of the right hip joint.
Fig. 2-B: Shows solid fusion of the right hip joint, three years after operation.

dure is completed by thoroughly impacting the hip joint again to assure a dovetailing of the laminated cartilage. If this is accomplished, much delay in procuring firm bony union can be avoided; and the patient will experience very little, if any, discomfort in the hip joint after operation.

Shock during the operation is greatly minimized by the fact that the hip has not been dislocated. Transfusions of whole blood are used, as indicated. No plaster cast is applied, and the patient is allowed to turn freely in bed during the entire postoperative period. The head of the bed can be raised slightly, since there is fixed flexion of the hip of 30 degrees, but undue strain should be avoided until healing has been well established. Since a cast is not used, early motion of the knee is facilitated; and the development of stiffness in that joint is prevented. The patient can be placed face downward in bed, and motion of the knee joint can be started very soon after the operation. Usually the authors' patients have been up on crutches in from four to six weeks; it is believed that perhaps this period of confinement to bed could be reduced still further, without risk of interference with fusion of the joint. The amount of activity permitted, however, must be governed by a proper respect for the underlying principles of bone healing, which means that undue stress and strain should not be applied until sufficient healing has been accomplished to ensure union. If this precept is followed, there will be no tendency toward recurrence of the deformity; and the best functional result will be assured.

RESULTS

During the past few years, this procedure has been carried out on ten patients with painful hips; in most of them, the disability was caused by chronic hypertrophic arthritis.

FIG. 3-A FIG. 3-B

Fig. 3-A: Case 6. Roentgenogram showing old fracture of the neck of the left femur, with pronounced aseptic necrosis of the femoral head.

Fig. 3-B: Solid fusion of the hip joint is seen, twenty months after operation.

The clinical data in these cases are summarized in Table I. All but three of the patients were fifty years old or over; five were men and five were women. There have been no postoperative complications, and complete fusion of the joint has occurred in all cases (Figs. 1-B, 2-B, 3-B, 4-B, 5-C, and 6-D). In one instance (Case 1) the authors had made two unsuccessful attempts at fusion of the joint by insertion of a graft and external fixation in plaster, a year and two years previously. Adduction and excessive flexion deformities, present before operation, have been overcome (Figs. 6-A and 6-B) in all but one instance, in which slight adduction persists (Case 6). This apparently was due to insufficient correction at the time of operation.

DISCUSSION

Some authors[4] have emphasized that it is at times difficult to persuade patients to submit to arthrodesis of the hip, since they object to having a permanently stiff joint. The authors have not encountered such objections in their patients. In most cases, the joint is almost completely ankylosed anyway; but the patients have pain because some movement is retained and because the joint is fixed in a bad position. We find that they are so anxious to have their pain relieved that they are not unduly concerned about acquiring a stiff joint in the process. The point has also been made that, if there is pain or other evidence of arthritic involvement in the spine, the hip fusion will not be successful in relieving the pain. In several of the authors' patients, correction of the flexion-adduction deformity of the hip joint apparently contributed also to relief of pain in the back, which had been present before operation.

With the technique described, no serious surgical shock has been observed. The patients have been comfortable after operation, and no complications have developed. Since movement in bed is possible throughout the postoperative period, and the knee

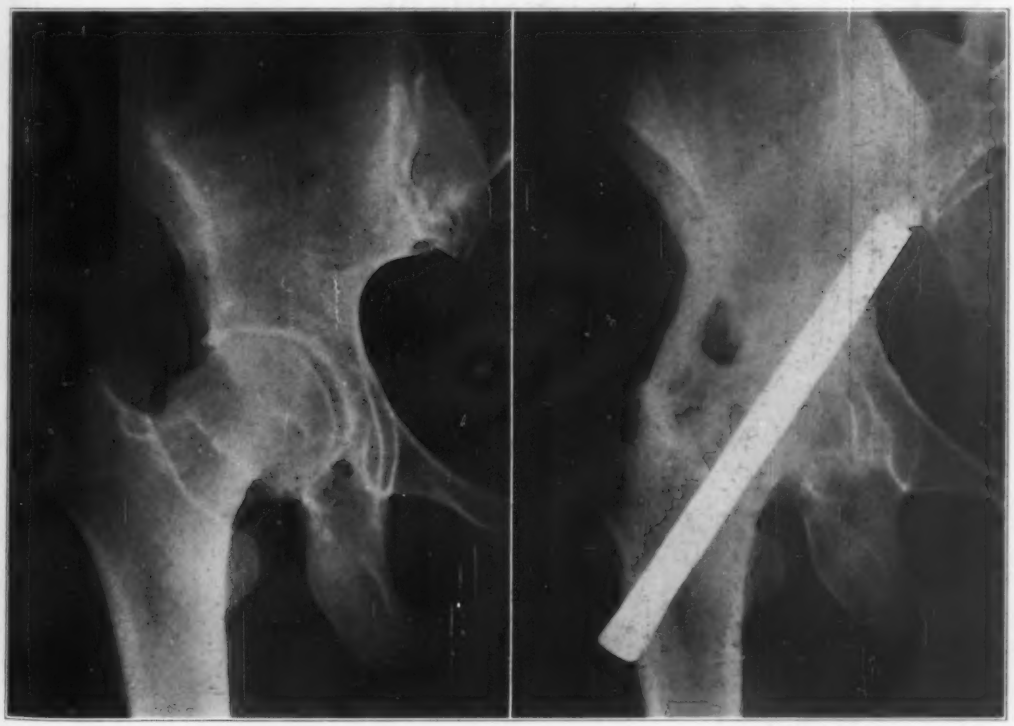

FIG. 4-A FIG. 4-B

Fig. 4-A: Case 7. Roentgenogram shows low-grade infectious arthritis of the right hip.
Fig. 4-B: Shows solid fusion of the hip joint, thirteen months after operation.

TABLE I

CLINICAL RESULTS FOLLOWING MODIFIED ONE-STAGE PROCEDURE FOR ARTHODESIS OF THE HIP JOINT

Case No.	Sex	Age	Condition Before Operation	Date of Operation	Clinical Results *
1	M.	50	Traumatic arthritis. For several years unable to walk without crutches, because of pain. Using a graft and cast, the authors had made two unsuccessful attempts to fuse the left hip joint.	Feb. 1, 1938	Complete relief of pain. Excellent fusion had occurred four months after operation.
2	F.	62	Hypertrophic arthritis. Severe pain on attempted motion. Flexion deformity of 45 degrees in left hip.	Oct. 9, 1941	Was walking on crutches eight weeks after operation, without pain. Hip joint fused in good position. Two years later, patient reported she was walking well and had no pain.
3	F.	38	Hypertrophic arthritis of right hip. Adduction of 15 degrees; flexion of 80 degrees.	Sept. 4, 1942	Was walking with crutches, without pain, eight weeks after operation. Hip deformity corrected. Four years later, patient stated that she could walk as far as she desired, and had no difficulty in sitting. Hip fused.
4	M.	64	Hypertrophic arthritis. Pain of increasing severity. Only a few degrees of motion in right hip. Joint position satisfactory.	Apr. 13, 1943	Patient walked with crutches, four weeks after operation. Hip joint solidly fused at ten weeks. Two years after operation, was walking well, with no pain.
5	M.	55	Hypertrophic arthritis of right hip. Flexion of 35 degrees; adduction of 20 degrees.	Aug. 24, 1943	Was walking with crutches in four weeks. Hip was solidly fused in good position at four and one-half months. Patient was walking well, with no pain, when seen eleven months after operation.

TABLE I (*Continued*)

Case No.	Sex	Age	Condition Before Operation	Date of Operation	Clinical Results *
6	F.	57	Aseptic necrosis of femoral head after fracture of neck of left femur. Flexion deformity of 40 degrees; adduction of 15 degrees. Severe pain.	July 20, 1944	Walking with crutches five weeks after operation, without pain. Hip was solidly fused when seen four months after operation, and patient had no pain. Adduction deformity of 5 degrees persisted, requiring slight lift on heel.
7	F.	25	Old infectious arthritis. Severe pain for five years, which acetabuloplasty had failed to relieve. Right hip in good functional position.	Apr. 18, 1944	Was walking on crutches six weeks after operation. When seen a year later, hip was solidly fused in good position. Patient walked well, with no pain.
8	M.	61	Hypertrophic arthritis; severe pain. Adduction deformity of 20 degrees. One inch apparent shortening of left lower extremity.	Mar. 8, 1946	Was walking on crutches, five weeks after operation. Three months afterward, the hip was solidly fused in corrected position. Apparent limb shortening overcome and patient walking well, without pain.
9	F.	54	Hypertrophic arthritis of right hip. Severe pain. Flexion of 45 degrees; adduction of 20 degrees.	Feb. 26, 1946	Was walking with crutches, five weeks after operation. Solid fusion had occurred five months after operation, and corrected position was maintained. Patient was walking well, without pain.
10	M.	37	Hypertrophic arthritis of left hip; old slipped epiphysis. Adduction deformity of 25 degrees; flexion of 25 degrees.	May 2, 1946	Walking with crutches six weeks after operation. At four months, hip was solidly fused and deformity was corrected. Patient was walking well, without pain.

* The time required for solid fusion is not known in each case, because of the variable intervals at which the patients returned for observation. The time given refers to the follow-up studies only.

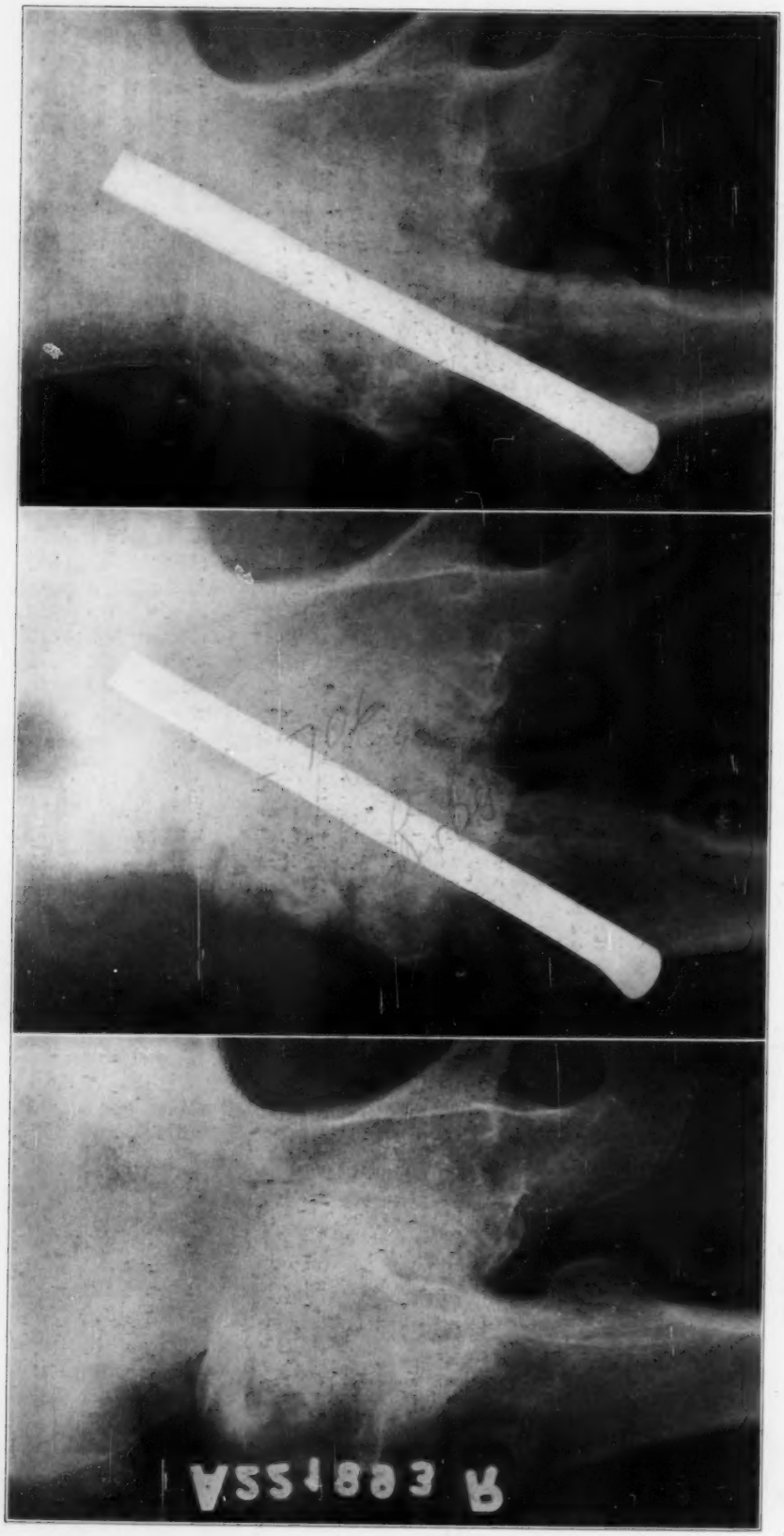

FIG. 5-A FIG. 5-B FIG. 5-C

Fig. 5-A: Case 9. Roentgenogram, taken before operation, shows hypertrophic arthritis of the right hip joint.
Fig. 5-B: Roentgenogram, two months after operation, shows graft and nail in position.
Fig. 5-C: Showing solid fusion of the right hip joint, eight months after operation.

FIG. 6-A FIG. 6-B

Fig. 6-A: Case 10. Photograph taken before operation shows pelvic tilt and apparent shortening, due to the adduction and flexion deformity.

Fig. 6-B: Photograph after operation shows correction of the pelvic tilt and of the apparent shortening of the lower extremity.

FIG. 6-C FIG. 6-D

Fig. 6-C: Roentgenogram, taken before operation, shows hypertrophic arthritis of the left hip joint.

Fig. 6-D: Shows solid fusion, five months after operation.

joints are kept mobile, there has been no increased stiffness in the knees or other joints during the period of fusion of the hip joint.

Although the present series of cases is not large, fusion has been achieved by this simplified technique of arthrodesis in a higher proportion of instances than has been reported by other authors, using other surgical methods. With earlier techniques and the use of external fixation, failure or incomplete fusion occurred in as many as 50 per cent. of the cases in some series. The results achieved with various techniques employing internal fixation[7,9,13] have been more satisfactory in this respect, but have included some failures to achieve bony union. Furthermore, these other methods present greater surgical risk, are more difficult to perform, usually require two operations, and keep the patient incapacitated for a much longer period.

The simplified one-stage procedure described here seems to recommend itself on the basis that it embodies the best principles of the surgical techniques described previously. In addition, it overcomes their main difficulties, corrects deformities, provides the best possible chance for joint fusion, avoids the hazards presented by plaster immobilization, and greatly reduces the length of time spent in the hospital.

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OSTEOCHONDRITIS DISSECANS OF THE TALUS

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The aseptic separation of a fragment of articular cartilage, with or without subchondral bone, known as osteochondritis dissecans, although more common at the knee, may involve any joint. Cases have been reported of lesions involving the shoulder, the elbow, the hip, the wrist, the metatarsophalangeal joints, and the ankle [3, 6, 8, 15, 20, 26]. Involvement of the ankle is usually in the trochlear portion of the talus, and has been considered very uncommon. Sporadic cases of osteochondritis dissecans of the talus have been reported; in 1941, Mensor and Melody reviewed the literature on the subject and reported one case, which was the twentieth case reported up to that time. Since then, four additional papers, reporting a total of nine new cases, have appeared in the literature [1, 9, 10, 19]. In addition, the authors have found a report made by Schnaberth in 1939, in which a case with extensive involvement of the talus was described. In view of the fact that, during the past four years, the authors have been able to collect a series of thirteen patients with fourteen ankles involved, and have discovered three additional cases through personal communications, it is felt worth while to report these cases and to discuss the condition in some detail.

ETIOLOGY

Although the disease now known as osteochondritis dissecans was first described by Monro in 1738, the causative factor or factors have been obscure and, in consequence thereof, the theories as to etiology are numerous. König described this condition in 1887 and stated that, without injury, fragments of various sizes become separated from the joint ends in consequence of a process as yet unexplained. In 1905 he gave the condition the name by which it is now generally known. Wagoner and Cohn, in 1931, thoroughly reviewed the theories of etiology of osteochondritis dissecans, and suggested the possibility that heredity or congenital factors were of etiological importance. Bernstein, in 1925, considered the lesions to occur in individuals congenitally predisposed to aseptic separation of an articular osteocartilaginous fragment. Conway, in his discussion of the condition in 1937, mentioned embolism of the epiphyseal arteries, a low-grade infectious process, and a congenital excessive brittleness of epiphyseal bone, leading to subchondral fracture, as possible non-traumatic etiological factors. He, however, discounted these factors in favor of trauma, even though mild, as the causative agent. Monro originally felt that the appearance of loose bodies within a joint was due to trauma; and Axhausen, in 1912, proposed the theory that, as a result of impaction from the opposing articular surface, the blood vessels to the part are damaged, either with or without partial fracture, according to the severity of the violence. This leads to necrosis of the area supplied by the damaged vessels; and as a consequence there forms a zone of absorption, resulting in gradual separation and eventual extrusion of the dead portion of the articular surface into the joint.

Fairbank believed that trauma, pure and simple, without vascular disturbance, is the sole etiological agent. Mercer supported this view, stating that, because of the rich blood supply of the subchondral bone, a vascular disturbance with aseptic sequestration of an osteochondral fragment is unlikely.

The authors are of the opinion that the condition is due to trauma—either a single recognized episode or repeated minor unnoticed traumata—with localized vascular diminution, leading to avascular separation of the loose fragment of cartilage and subchondral bone.

CLINICAL FEATURES

History: The usual presenting symptom of a patient with osteochondritis dissecans of the talus is pain and tenderness at the site of the lesion. In some cases, swelling and intra-articular effusion are present. Pain and swelling subside with rest and elevation of the leg; however, tenderness usually persists for an indefinite length of time. The majority of patients give a history of trauma. In some cases the injury is relatively mild; some patients give a history of repeated minor traumata; and in a few cases there is a history of direct trauma across the dorsum of the foot and ankle. Patients usually present themselves for examination because of chronic ankle pain or fatigue; and in some instances the lesion is found during roentgenographic examination for an acute sprain of the ankle.

FIG. 1

Case 1. Anteroposterior roentgenogram shows a moderately advanced lesion of osteochondritis dissecans, involving the superomedial articular surface of the talus.

Physical Examination: Physical examination may or may not disclose swelling, depending upon the stage of the lesion. In early cases, swelling is absent. In the long-standing case, however, chronic oedema and periarticular thickening may be present. There is usually local tenderness, at times exquisite, at the site of the lesion. There are no signs of inflammation. Limitation of motion, locking, instability, giving way, or palpation of a loose body is dependent upon the stage of the lesion, and may be present in the advanced case. Joint motion is usually within normal limits, and physical examination in early cases may be remarkable chiefly because of its negative findings.

LABORATORY DATA

In this series of cases, blood studies, including the sedimentation rate, calcium and phosphorus determinations, serological tests for syphilis, and the usual determinations of red cells, white cells, and hemoglobin, were all within normal limits. Urinalyses, including tests for Bence-Jones bodies, were negative. Cultures taken from the site of the lesion at the time of operation were all negative, when grown both aerobically and anaerobically.

ROENTGENOGRAMS

Although roentgenographic examination is the principal method of diagnosis, routine anteroposterior and lateral views often fail to demonstrate the lesion. This failure is probably due to the fact that the superolateral or medial pole of the talus, which is the usual site of the lesion, may be hidden by the superimposed lateral or medial malleolus. However, careful oblique projections will demonstrate the lesion (Figs. 2-A, 2-B, and 2-C, and 4-A to 4-E, inclusive).

In eleven of the fourteen cases studied by the authors, the lesion was located on the medial border of the superior articular surface of the talus, while in the remaining three it was located on the superolateral articular surface. Mensor and Melody described the use of tomography in making the diagnosis. However, this method entails the use of special equipment; and the authors feel that careful anteroposterior, lateral, and oblique roentgenograms are sufficiently accurate to suggest the diagnosis without the necessity for special equipment.

PATHOLOGICAL FINDINGS

The pathological findings in osteochondritis dissecans of the talus are similar in all respects to those found in osteochondritis dissecans of the knee or of any other joint. The gross appearance is, of course, dependent upon the stage of the lesion, and may vary from a cartilage of normal appearance with slight chondral softening and discoloration over the site of the lesion to an actual defect in the articular surface of the affected bone, with an osteocartilaginous loose body lying free within the joint. At the usual stage at which the lesion is seen, there is a yellowish discoloration of the cartilage over the site of the osteo-

FIG. 2-A

FIG. 2-B

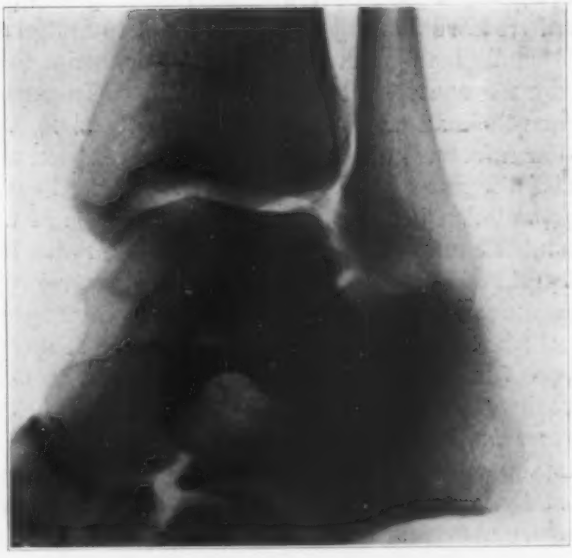

FIG. 2-C

Case 2. Roentgenograms show lesion of osteochondritis dissecans on the superolateral aspect of the talus, adjacent to the lateral malleolus.

Fig. 2-A: In the anteroposterior view the lesion may be seen, but is partially hidden by the lateral malleolus.

Fig. 2-B: In the lateral view the lesion cannot be demonstrated.

Fig. 2-C: The location, size, and extent of the lesion can best be demonstrated in the oblique view.

chondral fragment; softening of this area readily demarcates the periphery of the lesion. Upon incision of the cartilage at the circumference of the lesion, the involved portion usually becomes separated very readily from the body of the talus, leaving a somewhat sclerotic-appearing excavated base. In the moderately advanced case, there is frequently an overhanging cartilaginous lip; but, if the process has progressed to the point of separation of the loose fragment, the base may be saucerized spontaneously. The loose fragment is covered by smooth articular cartilage on one surface, and there is a thin layer of subchondral bone beneath the cartilage. Microscopic examination discloses a viable, although somewhat fibrillated, hyaline cartilage; the subchondral bone is of decreased vascularity

and, in advanced cases, is necrotic. Morton and Crysler, in discussing osteochondritis dissecans of the supratrochlear septum, considered the microscopic pathological appearance to be that of necrosis with foreign-body giant cells and low-grade aseptic inflammation. The authors have found no evidence of inflammation in any of their cases.

TREATMENT

In the early cases, in which the lesion is discovered accidentally and no definite symptoms are referable to the site of the lesion, operative intervention should be delayed until symptoms develop, or until roentgenograms demonstrate unquestionable progression of the lesion. When the diagnosis has been established and the patient is having symptoms referable to the site of the lesion, surgical intervention is the only satisfactory method of treatment. Cases of spontaneous healing of the lesions of osteochondritis dissecans have been reported, but the authors agree with Cohen that they probably represent healing of an osteochondral fracture rather than true osteochondritis dissecans.

OPERATIVE TECHNIQUE

Surgical Approach: The particular surgical approach to be used is necessarily determined by the location of the lesion. If the lesion is on the superomedial aspect of the talus, an anteromedial incision may suffice. However, in some cases the lesion may be hidden completely by the medial malleolus; and exposure of the site of the lesion may be extremely difficult, if not impossible, through an anteromedial incision. In this type of case the authors have employed a modification of the approach first described by König and Schäfer. In the modification of this method, a straight anteromedial incision is made just anterior to the medial malleolus. Through this incision the joint may be opened, and an estimate of the availability of the lesion can be made. If the lesion cannot be reached through this approach, the incision is extended in a curved fashion around the tip of the malleolus; the malleolus is then exposed and an osteotomy is performed across its base, care being taken to avoid trauma to the posterior tibial tendon, vessels, and nerve. The authors have found it very convenient to first place a drill hole obliquely from the tip of the malleolus into the body of the tibia, prior to osteotomy. This method greatly facilitates the anatomical repositioning of the fragments at the completion of the procedure, when the malleolus is replaced in its normal position and held by means of a single screw. After osteotomy of the malleolus, sharp eversion of the foot brings the lesion on the superomedial aspect readily into view. The standard anterolateral approach is used for exposure of the lesion lying at the superolateral pole of the talus; or, if the site of abnormality should lie more posteriorly, as was the situation in one of the authors' cases, the posterolateral incision may be used to good advantage. Waring has experienced difficulty in the exposure of a lateral lesion through an anterolateral approach, and concurs with the authors in the opinion that the approach described by Gatellier would be useful in this type of lesion. When this approach is used, an osteotomy of the fibula is carried out approximately three inches above its distal end. The distal ligamentous attachments are preserved, but the fibula is otherwise stripped of soft-tissue attachments, including the distal portion of the tibiofibular ligament. The distal portion of the fibula is then laid back distally, thereby exposing the lateral compartment of the ankle joint in an excellent fashion. After completion of the procedure, the fibula is replaced in its normal position and is fixed to the tibia by means of a single transversely placed screw, the soft tissues being sutured in their respective layers. The authors have employed this method with success in the open reduction of comminuted fractures involving the medial malleolus, the lateral malleolus, and the posterior lip of the tibia at the ankle (the so-called "trimalleolar" fracture), but have not employed it in the exposure of osteochondritis dissecans of the talus. Should the lesion lie posteriorly, the posterior approach with tenotomy of the tendo calcaneus may be used. Because the osteoplastic and tendoplastic procedures entail more

extensive surgery and prolonged convalescence, the simple soft-tissue approaches are to be preferred. However, the approach used should be determined carefully before operation by exact location of the lesion, roentgenographically. If the soft-tissue approach is considered inadequate, the more extensive procedure should be employed without hesitation.

Operative Procedure: In the well-established case, simple removal of the separated fragment is all that is necessary, since the remaining defect has usually been filled in and presents a smooth surface. The remaining defect in the talus should be saucerized if there is an overhanging cartilaginous lip, and all loose cartilaginous fragments should be excised. Careful exploration of the joint for loose bodies should be done routinely.

POSTOPERATIVE TREATMENT

Postoperative immobilization is dependent upon the type of approach used, and is unnecessary unless an osteoplastic or tendoplastic procedure is employed. Similarly, weight-bearing and active motion are allowed as soon as the healing of the operative trauma permits. If a purely soft-tissue approach is used, active use of the part is usually begun within from ten to fourteen days. Postoperative physical therapy is not required, but whirlpool baths and supervised active motion may hasten convalescence.

PROGNOSIS

The prognosis in cases of osteochondritis dissecans of the talus is dependent, of course, upon the stage of the disease at the time the diagnosis was made and the operation was performed. In early cases, without actual separation of the osteochondral fragment and without arthritic changes, the prognosis is excellent. If arthritic changes have developed, or if actual separation of the fragment has occurred, there is greater likelihood of permanent traumatic articular damage with residual disability. It is conceivable that, should articular damage be extensive, arthrodesis of the ankle might be required. Although the authors have not seen a case of such severity, an extensive case involving the talus was described by Schnaberth, who employed arthrodesis as the treatment of necessity.

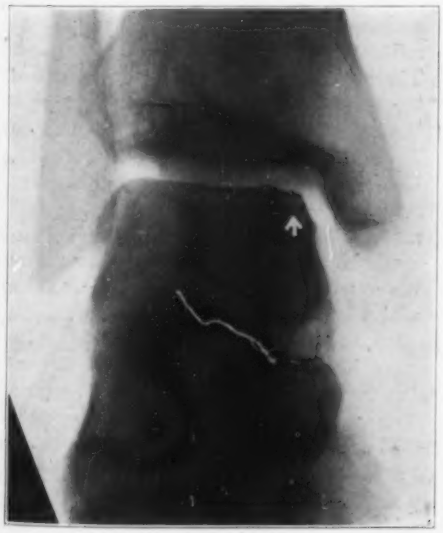

FIG. 3-A

FIG. 3-B

Case 3. Anteroposterior roentgenograms show small lesion of osteochondritis dissecans at the superomedial articular surface of each talus.

Fig. 3-A: Film of right ankle, taken for comparison at time patient was examined.

Fig. 3-B: Film of left ankle was taken because of pain and tenderness of three years' duration, localized just anterior to the medial malleolus.

FIG. 4-A

FIG. 4-B

FIG. 4-C

Fig. 4-A: Case 7. Anteroposterior roentgenogram, showing questionable lesion at the superomedial articular surface of the talus.

Fig. 4-B: In the lateral view, the lesion cannot be seen.

Fig. 4-C: The lesion of osteochondritis dissecans is clearly demonstrated in the oblique view.

CASE REPORTS

CASE 3. This patient, a white male Army mess officer, twenty-seven years old, complained of pain about the left medial malleolus, which had been present intermittently for approximately three years. The patient recalled no single incident of trauma to either ankle, and had gone through the Army Air Forces Officers Training School without much difficulty. He did, however, give a history of frequent minor or moderately severe sprains of each ankle. Physical examination was not remarkable, except for slight swelling over the anteromedial portion of the left ankle with slight tenderness over the talus, just lateral to the medial malleolus. Joint motion was normal, not crepitant, and not painful. On roentgenographic examination of the left ankle, the lesion of osteochondritis dissecans, involving the superomedial aspect of the talus, was discovered. Roentgenograms of the right ankle, taken for comparison, demonstrated an identical lesion at the same site as that present in the left ankle (Figs. 3-A and 3-B). The condition was described to this patient and operative intervention was suggested; but, since he felt that he was not having sufficient trouble with either ankle to justify an operation, he was treated conservatively with ankle strappings and physical therapy. His condition was followed for approximately six months after the diagnosis had been made; when last seen, he was continuing to have pain in the left ankle with slight swelling, but no symptoms referable to the right ankle.

CASE 6. This patient, a radio operator, thirty-four years of age, gave the history of having had his right ankle give way when he arose from a chair, twenty-two months prior to the first examination. The morning after this incident, the ankle was swollen and painful on the anteromedial aspect. Roentgenograms, taken by his local physician, were reported to reveal "a hole in the bone, but no fracture". Since the onset of the present

illness, the patient had had intermittent aching pain in the ankle, not related to walking or weight-bearing. There was no known history of trauma. Physical examination was not remarkable, except for localized tenderness over the talus, just anterior to the medial malleolus. The results of routine laboratory studies were within normal limits. Roentgenograms disclosed a flat elliptic loose body, lying in an excavated area at the medial aspect of the superior articular surface of the talus.

Arthrotomy of the ankle, by the method of osteotomy of the medial malleolus, was done on April 18, 1944. The osteochondral loose body was removed readily; the malleolus was replaced and held with a single screw; and the soft tissues were closed in layers. The postoperative course was entirely uneventful. The pathological diagnosis was "articular osteochondral loose body". This patient was discharged from the hospital on May 29, 1944, and was seen in the Out-Patient Clinic until December 1945. Roentgenograms, taken in November 1945, showed solid union at the site of osteotomy, with no demonstrable arthritic changes being present. On examination, the patient had a full range of motion in the ankle with no crepitus or swelling. He did, however, complain of mild aching pain with changes of weather or after prolonged standing or walking.

CASE 7. This patient, a white policeman, twenty-eight years old, had had no trouble with his right ankle until May 19, 1946, when he stepped off a street car onto an irregularity in the pavement, forcefully inverting the left foot against the ankle. On May 20, a diagnosis of fracture of the talus was made by his local doctor, and a plaster-of-Paris boot cast was applied under anaesthesia. The patient had a great deal of pain in the ankle while in the cast and, on June 8, the cast was removed, and one of the authors (R. B. R.) was called into consultation. Examination at that time showed moderate oedema with pitting (one plus) over the dorsum of the foot. Marked pain was present about the anterior portion of the ankle joint, particularly on the medial aspect, with exquisite tenderness over the superomedial portion of the talus just lateral to the medial malleolus. There was slight pain associated with stretching of the lateral ligaments. Inversion of the foot caused pain in the medial portion of the ankle joint, over the site of tenderness in the talus. All motion of the ankle and toes was limited 50 per cent. by swelling; subtalar motion was approximately normal. Roentgenograms in the anteroposterior, lateral, and oblique planes demonstrated the typical lesion of osteochondritis dissecans; an osteochondral loose fragment, one by one centimeter, was lying in a defect at the superomedial pole of the talus (Figs. 4-A, 4-B, and 4-C). The base of this defect was sclerotic, with the osteochondral fragment apparently lying loose in this bed. The patient was treated by contrast baths, elevation, and active and passive motion, without weight-bearing, until there was no swelling about the ankle and the circulatory status of the foot and ankle had returned to approximately normal.

On July 9, 1946, the right ankle joint was explored by the authors' osteoplastic transmalleolar approach. A typical lesion of osteochondritis dissecans was found at the superomedial pole of the talus; the loose

FIG. 4-D

FIG. 4-E

Fig. 4-D: Postoperative anteroposterior view, showing excavated area in talus at site of removal of loose fragment, and reapposition of medial malleolus after osteoplastic approach.
Fig. 4-E: Lateral view shows screw fixation after medial osteoplastic approach.

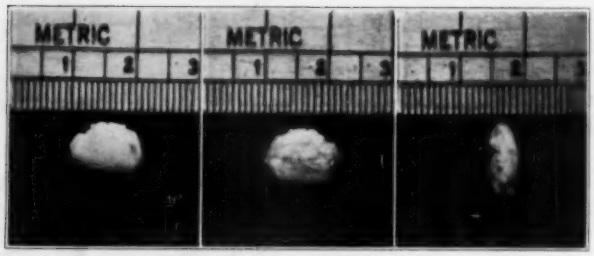

FIG. 4-F

Articular cartilage surface (left) and subchondral osseous surface (center) of osteochondral loose fragment. Edge-view of fragment, showing articular cartilage of approximately normal thickness with thin layer of detached subchondral bone, is seen at right.

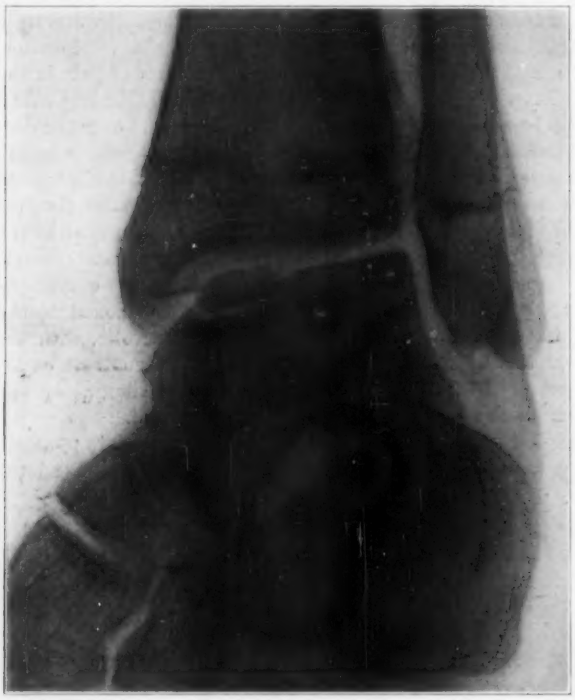

FIG. 5

Case 9. Oblique roentgenogram shows a large well-advanced lesion of osteochondritis dissecans, involving the superomedial articular surface of the talus. Note loose-body formation, cavitation, and sclerosis of bone at periphery of excavated area in talus.

osteochondral fragment was removed; and the base of the defect was saucerized. The osteotomized medial malleolus was replaced by means of a single obliquely set Vitallium screw (Figs. 4-D and 4-E). The ankle was immobilized for three weeks in a plaster-of-Paris boot cast, after which a plaster-of-Paris walking boot cast was applied. The cast was removed six weeks after operation, and the patient was allowed to walk with an adhesive strapping on his ankle. Except for some stiffness and swelling, subsequent to immobilization, he had no pain or tenderness about the ankle, and stated that there was no tenderness at the site of the lesion such as had existed prior to operation.

This case is too recent to permit a more adequate follow-up. Microscopic examination of the specimen removed (Fig. 4-F) showed fibrillation of the articular cartilage; the bone surface was of decreased vascularity, although not completely necrotic. The pathological diagnosis was "osteochondral articular loose body, secondary to osteochondritis dissecans of the astragalus".

CASE 9. This patient, a German prisoner of war, twenty-one years old, gave a history of having had a tree limb fall across the dorsal aspect of his left ankle while he was under shell fire, ten months before admission to the hospital. For three weeks after the injury he had a painful swelling of the ankle, which gradually subsided. Following subsidence of the acute traumatic reaction, he had only occasional twinges of pain in the ankle until two months before admission, when he began to have increasing pain and swelling. Physical examination showed moderate swelling about the ankle, with fairly diffuse tenderness over the anterior portion of the ankle. Roentgenograms disclosed a large excavated defect at the superomedial pole of the talus; in this defect was a large loose body of increased density (Fig. 5).

On August 28, 1945, an arthrotomy was performed, and the loose body was readily removed through an anteromedial incision. The postoperative course was uneventful. A follow-up study of this case was impossible, because of the military circumstances involved.

SUMMARY

In this series are presented thirteen cases of osteochondritis dissecans of the talus, one of which showed bilateral symmetrical involvement of the ankle (Table I). Twelve of the patients were males and one was a female; all were white. The occupation of the individual apparently had no relation to the onset or causation of the condition.

Trauma is a major etiological factor, although in this series four patients gave no history of ankle injury. Seven of the patients had had either severe sprains or recurrent sprains of the involved ankle; two patients had had direct trauma. The duration of symptoms ranged from two months to four years, the average being 21.4 months. Since there

TABLE I

FINDINGS IN THIRTEEN CASES OF OSTEOCHONDRITIS DISSECANS OF THE TALUS, INVOLVING FOURTEEN ANKLES

Case No.	Sex	Age	Occupation	History of Trauma	Duration of Symptoms	Location of Lesion	Operation
1	Male	24	Soldier	Recurrent sprains	3 years	Medial (right)	No
2	Male	22	Pilot	Sprain	3 years	Lateral (left)	No
3	Male	27	Mess officer	Frequent sprains	3 years	Medial (right and left) (Bilateral involvement)	No
4	Male	24	Navigator	Sprain	4 years	Medial (right)	No
5	Male	19	Military police	Direct trauma	2 years	Lateral (left)	No
6	Male	34	Radio operator	None	2 years	Medial (right)	Yes
7	Male	28	Policeman	None	2 months	Medial (right)	Yes
8	Female	26	Red Cross worker	Severe sprain, 13 years before	2 years	Medial (left)	No
9	Male	21	Prisoner of war	Direct trauma	10 months	Medial (left)	Yes
10	Male	23	Pilot	Sprain in plane crash	8 months	Medial (right)	Yes
11	Male	19	Aviation mechanic	Recurrent sprains	1 year	Lateral (right)	Yes
12	Male	24	Pharmacist	None	2 years	Medial (left)	Yes
13	Male	20	Infantryman	None	6 months	Medial (right)	No

was involvement of the right ankle in eight cases and of the left ankle in six cases, there would seem to be no more likelihood of the lesion appearing on one side of the body than on the other. Of the fourteen ankles involved, three lesions were located on the superolateral aspect of the talus; in eleven cases the site of involvement was on the superomedial articular surface of the talus. In one case there was bilateral involvement, with the lesions located on the superomedial aspect of each talus, adjacent to the medial malleolus. In six of the cases, operation was performed. That surgical intervention was not employed in more cases was due to several factors. Some patients did not desire operation and, since most of these cases occurred among military personnel, surgical intervention was not employed, because of existing Army regulations which prohibited operation in long-standing cases.

DISCUSSION

The authors have reviewed the literature since 1941 on osteochondritis dissecans of the talus. Mensor and Melody in 1941 accumulated a total of twenty cases, including one of their own. Since 1941, nine additional cases have been reported. The paucity of these cases would seem to indicate that the condition is rare. During the past four years, however, the authors have seen a total of thirteen cases with involvement of fourteen ankles, and have roentgenograms of three additional cases seen by Eberhard, indicating that the condition, although uncommon, is certainly not rare. All of Eberhard's cases were in the superolateral articular surface of the talus and, if included with this series, would present a total of seventeen cases, with the lesion in the superomedial portion of the talus in eleven cases and in the superolateral location in six instances. With the condition in mind and with careful roentgenographic study, it is probable that the diagnosis will be made with increasing frequency.

Anteroposterior and lateral views do not always reveal the lesion. Careful oblique views will often expose a lesion, hidden by one of the malleoli. Tomography or laminagraphy, although an adjunct in making the diagnosis, is not necessary routinely. A patient presenting a typical history of repeated sprains, with localized tenderness over the anterior

aspect of the talus and negative roentgenographic findings, should be followed carefully, since subsequent roentgenograms may disclose the lesion.

Burr, in 1939, and Stein, Ikins, and Lowry, in 1944, stated that the "characteristic" location of the process in the talus is at the superomedial pole of the articular surface. The authors' finding of eleven lesions at the "characteristic" site and three lesions at the superolateral pole would indicate that, although found more frequently in the superomedial location, lesions do occur at the superolateral pole of the talus. Therefore, no one site should be designated as "characteristic".

Various writers, including Wagoner and Cohn, Blanco, and others, have stated that the lesions of osteochondritis dissecans are usually monarticular; and that, when more than one joint is involved, the lesions are likely to be bilateral. Case 3 in this series tends to confirm the opinions of these writers. In the case reports available, the authors have been unable to locate a previous case with bilateral involvement of the talus.

Treatment should consist of excision of the loose fragment and saucerization of the remaining defect in the articular surface of the talus. The surgical approach to the ankle joint should be considered carefully, and should be chosen only after roentgenographic study and determination of the exact location of the lesion.

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(*Continued on page 710*)

OBLIQUE SUBCERVICAL (REVERSE INTERTROCHANTERIC) FRACTURES OF THE FEMUR

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The purpose of this paper is to describe a rare fracture that may be termed an "oblique subcervical intertrochanteric" or "reverse intertrochanteric" fracture of the femur. This fracture has been seen before, but has never, to the author's knowledge, been described or recognized as a separate, definite entity. In Harlem Hospital, two cases have been observed during the period from 1937 to 1946 (eight and one-half years), during which time the records show that five patients with pertrochanteric fractures and 177 patients with intertrochanteric fractures were treated.

The fracture may be described as one that begins at the lower border of the base of the neck of the femur and extends obliquely downward and outward between the two trochanters, in the long axis of the neck of the femur. The fracture line would bisect at almost a right angle the line of the more usual and frequent intertrochanteric fracture (Fig. 1).

A careful search of the available literature and of numerous standard textbooks failed to disclose an exact description of this fracture. It is important to describe the fracture separately from other fractures in this area because the mechanics involved, which have a distinct bearing upon treatment, are different. The physio-anatomical factors which deserve consideration in this connection are: (1) The fracture line begins between the two limbs of the iliofemoral or Y ligament, the upper limb of the ligament being attached to the upper fragment and the lower limb to the lower fragment. (2) The muscles attached to the greater trochanter do not influence in any way the movement or position of the distal fragment. In addition to the attachment of the lower limb of the iliofemoral ligament, the iliopsoas is attached to the lesser trochanter and tends to draw the lower fragment upward and inward underneath the neck and head of the femur. In fact, the mechanical arrangement is such as to produce in effect the same results as a low subcervical osteotomy in the same axis as the neck of the femur.

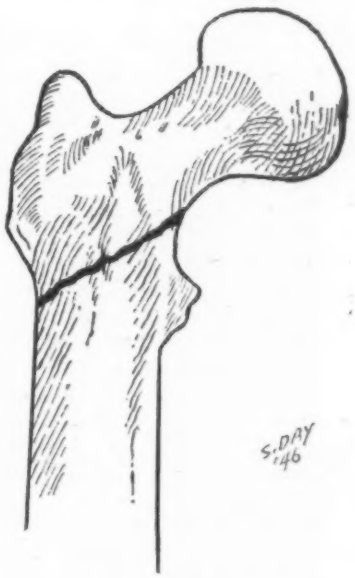

FIG. 1

Drawing of a reverse intertrochanteric fracture.

This fracture is produced by indirect violence, with the thigh in the position of hyperextension, in a patient with muscular and ligamentous weakness and increased bone brittleness. Its infrequent incidence is more clearly understood when we realize that it traverses the femur against its reinforcing cancellous lamellae and calcar femorale.

The term intertrochanteric fracture is used because these fractures follow the anatomical intertrochanteric lines of the upper end of the femur. The fracture under discussion is, in fact, an axial subcervical intertrochanteric fracture, with the fracture line extending obliquely downward to the cortex, as a prolonged extension of the lower border of the neck of the femur. For this reason, the term reverse intertrochanteric fracture probably describes the condition better than any other concise phrase.

FIG. 2-A

Case 1, M. W. Roentgenogram of fracture at time of admission. Line of fracture is seen to extend upward in axis of neck of femur, midway between lesser and greater trochanters. This is the exact reverse of the so-called intertrochanteric fracture of the femur.

FIG. 2-B

FIG. 2-C

Fig. 2-B: Shows fracture four months later, after treatment in Russell traction. Callus formation may be seen.

Fig. 2-C: Lateral view of fracture.

REPORT OF CASES

CASE 1 (Hospital No. 221,599). M. W., a negro woman, aged sixty years, was admitted to the Harlem Hospital on September 12, 1944. Her chief complaint was that she had slipped and hurt her right lower extremity.

The patient had had infantile paralysis when she was a child, which affected her right lower extremity. She had been lame on this side for some months, and at one time could not walk on the leg. She did not know when she became able to walk, but after finishing high school she was able to do so. There had been no previous operations or other accidents.

At ten o'clock on the night of admission, the patient slipped and fell to the floor, striking her right hip, after which she suffered severe and continuous pain in the region of the hip. This pain was particularly marked on motion.

Physical examination showed an obese woman, lying in bed in a Thomas splint. There was tenderness around her right hip joint. Roentgenograms disclosed a fracture of the femur, which began at the junction of the lower border of the neck and extended obliquely downward and outward to the cortex,—a reverse intertrochanteric fracture. It bisected at practically a right angle the intertrochanteric line on that side.

The lower extremity was put into Russell traction. On December 1, 1944, the patient's general condition was good; she could rotate the limb but could not raise her heel from the bed; there was slight limitation of motion of the ankle joint. On January 1, 1945, roentgenograms showed that the distal fragments were slightly displaced medially; but bony union was present roentgenographically, and the patient could move her limb in all directions. She was discharged from the Hospital with a walking caliper splint, on January 12, 1945 (Figs. 2-A, 2-B, and 2-C).

CASE 2. B. B., a Spanish woman, aged seventy-six, was admitted to Harlem Hospital on January 5, 1945. She stated that, on the day before admission, she fell forward while going down some steps. She was unable to get up after the fall, because of intense pain in her right hip and vagina. No further history could

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 2, B. B. Subcervical or reverse intertrochanteric fracture of the femur. Extremity was in Thomas splint at the time patient was admitted to the Hospital.

Fig. 3-B: Shows position of fragments four and one-half months later. Patient had been treated by only an elastic spica around her hip. Marked callus formation is present. The lower fragment has been pulled inward and upward, while the upper fragment has been pulled outward. The result in this case is similar to that of a subtrochanteric osteotomy without internal fixation.

be obtained, because she was irrational and confused. No previous history of accidents or operations could be elicited.

Physical examination showed a very thin, frail, weak woman, lying in bed in a Thomas splint.

Roentgenograms at the time of admission showed what was called by the roentgenologist a comminuted intertrochanteric fracture of the neck of the femur, or an oblique axial subcervical fracture of the femur. The position of the fragments was good; the limb was in a Thomas splint. Her general condition was poor. Russell traction was applied for three days and then discontinued, because the patient became much weaker. Because of this fact an elastic bandage was used as a spica; and on the fourth day she was put in a wheel chair, since it was felt that she would die if allowed to stay in bed. It was difficult to get her cooperation, because for over a month she was confused mentally and, in addition, she did not understand English. She was discharged with a coxa vara deformity. She would not use her caliper splint, but at the end of four months she gradually gained in strength and was able to walk with a limp, using one crutch. Internal fixation would have produced better results in this case, if it had been possible to get the patient's consent for such an operation and her cooperation (Figs. 3-A and 3-B).

FIG. 4

Case 3, A. R. An atypical reverse intertrochanteric fracture. Patient was treated in Russell traction for three months.

CASE 3.* A. R., an Italian woman, sixty-eight years of age, who had been troubled with diabetes and arthritis for several years, gave the following history: In October 1943, while she was rising from a chair, the patient made a slight turn; in doing so, her left lower extremity slipped from under her and snapped.

The patient was treated by Russell traction for three months, and during this time there was evidence of callus formation (Fig. 4). She also showed generalized arthritis, which was especially marked in her hands and feet. At the end of six months she was able to walk without a brace, but she had two to three inches of shortening of her left lower extremity. A pressure ulcer developed over her left Achilles tendon, which had not healed in a year.

One significant feature of these cases is the fact that, in spite of the age of these women, all showed marked callus formation.

* This case is presented through the courtesy of Angelo A. Zingaro, M.D. The patient was observed by him in private practice, and she presented a fracture that was in many ways similar to a reverse intertrochanteric fracture. It was not typical, however, the fracture line extending farther down on the femur.

OSTEOCHONDRITIS DISSECANS OF THE TALUS

(*Continued from page 706*)

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ARTHROPLASTY OF THE HIP FOR CONGENITAL DISLOCATION IN CHILDREN*

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The primary purpose of this paper is to present an end-result study of an arthroplasty procedure, devised some years ago for treating congenital dislocation of the hip. There are certain indications for its use, and also contra-indications which should be stressed, as well as postoperative safeguards, which should be borne in mind in the care of patients undergoing this operation. Naturally, the author has been keenly interested not only in observing the functional results in patients operated upon ten or more years ago, but he has also been anxious to satisfy himself by repeated follow-up roentgenograms that the reconstruction of the originally deficient acetabulum has been retained as to size and depth, and that a practically normal joint space has been preserved over the years.

Twenty-five years ago, rather brutal and traumatizing methods of bloodless reduction were in vogue. The comparatively gentle methods of closed reduction, generally accepted and practised today, represent great progress in the treatment of this congenital anomaly. The range of painless motion that can be obtained by closed reduction today, in those cases in which reduction has been effected within the first few years of life, is adequate proof of the value of gentleness in using the so-called bloodless method. It is hoped, therefore, that this gentleness will be emphasized in teaching the technique to the younger orthopaedic surgeons, and that this teaching will result in a smaller number of patients with permanent stiffness, arthritic changes, or aseptic necrosis of the femoral head. On the other hand, an open reduction can be an even more gentle procedure and can be far more desirable than one attained by closed methods employing force and awkwardness, which may, however, appear satisfactory roentgenographically. Reduction alone is of doubtful value, if it results in a painful or almost stiff hip.

Undoubtedly our attention to this whole problem has, heretofore, been centered too much upon the bony components of the deformity and too little upon the soft-tissue changes present. It should be remembered that roentgenograms do not show bruised or contused muscles, the hourglass constriction of the capsule, or contraction of the abductor and adductor groups of muscles. These are formidable barriers to gentle reduction. In many of these cases, adequate preliminary traction should be an absolute prerequisite to any attempt at actual reduction, either closed or open.

The aim of the orthopaedic surgeon in treating congenital dislocation of the hip should be, first, gently to obtain an accurate anatomical reduction. This means that the head of the femur should be brought not only downward, but forward in relation to the sagittal plane of the body. Second, stability and an excellent range of motion should be the end result; and, third, the relationship of the head and acetabulum, as demonstrated by follow-up roentgenograms over a long period, should show development of the bony components progressing in a normal manner.

The arthroplasty operation reviewed here has already been described by the author, and the reader is referred to these previous articles. This paper deals with the posterior type of congenital dislocation, but the principle of the arthroplasty is also suitable for cases with anterior types of congenital dislocation. The technical aspects, the indications for use, and the postoperative care will be only briefly reviewed, with follow-up roentgenograms, made ten to thirteen years after operation in five of the early cases.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1947.

FIG. 1-A

FIG. 1-B

Fig. 1-A: P. Z., 1932. Preoperative roentgenogram at end of traction stage. Second operation was performed on December 5, 1932.

Fig. 1-B: P. Z., 1942. Roentgenogram ten years after operation. When last seen the patient had a normal range of motion and no shortening. Note restoration of the architecture of the hip joint following arthroplasty.

ARTHROPLASTY OPERATION

There have been no essential changes made in the method since it was published originally in 1932.

The first stage consists of demonstrating that the head of the femur can be pulled down to the level of the original acetabulum. Whether this can be done manually and checked by a "push-pull" roentgenogram, or whether a preliminary period of skin traction

FIG. 2-A.

B. A., 1935. Preoperative roentgenogram. Traction was used for three weeks before the second stage of the operation was performed on October 25, 1935.

FIG. 2-C

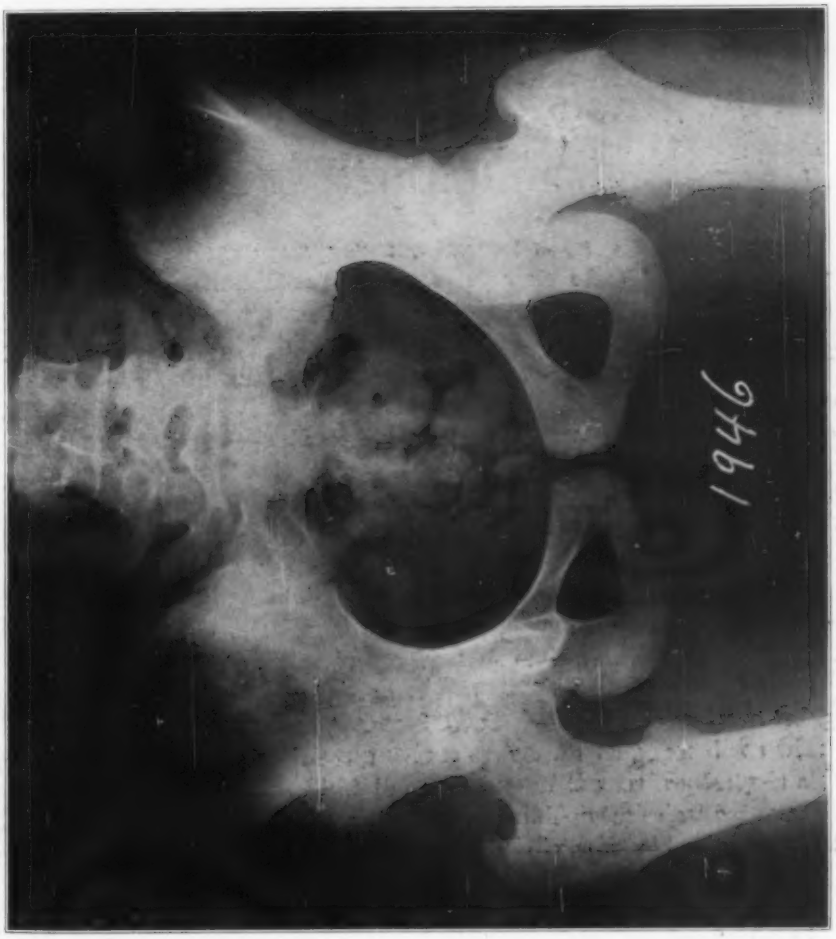

FIG. 2-B

B. A., 1946. Anteroposterior and lateral views taken eleven years after operation. Notice well-formed acetabulum and joint space, as well as appearance of head. Patient has normal function.

or skeletal traction applied to the affected extremity is required, while the opposite side is immobilized in a plaster spica, depends upon the individual case. However, complete relaxation of the soft tissues *must* be obtained, before the child is considered ready for the second stage. With some of the older patients, it has been found useful to stretch the hip thoroughly by the manoeuvre of straight-leg raising and abduction, with or without subcutaneous adductor tenotomy, before applying moleskin traction or skeletal traction. At examination, the degree of telescoping or laxity varies considerably; and, while not altogether dependent upon age, this is an important factor. If, however, the head of the femur is not brought down at least near the level of the original acetabulum before the second stage or open reduction is attempted, too much tension and too much force will be required at the second stage to reduce the head of the femur gently.

The second stage consists in exposing the hip joint by the lateral approach. The incision begins a finger's breadth posterior to the anterior superior spine of the ilium, curves downward, and crosses the shaft of the femur several inches below the tip of the greater trochanter. After the fascia has been divided and the tensor fasciae femoris has been retracted medially, the muscles attached to the greater trochanter come into view. The tip of the greater trochanter, to which are attached the abductor muscles, is cut through, and the capsule is easily separated by scissor dissection from the overlying group of muscles. The isthmus or hourglass contraction of the capsule can often be identified then. The capsule is divided at its narrowest point, and the head of the femur is inspected. The head is frequently found to be acorn-shaped or even normal in appearance, but it may be quite flattened and deformed. According to Wolff's law, the contour of the femoral head may later be restored to a remarkable degree by activity; yet, when the head is greatly deformed, the prognosis for full function must be guarded. By external rotation of the shaft of the femur, the capsular-covered head can be separated from the muscles posterior to the capsule. While the head is inspected, its cartilage is left intact, and no effort what-

FIG. 3-A

D. R., 1935. Preoperative roentgenogram of an unstable right hip that passively slipped in and out of place. The left femoral head is securely in place, but the acetabulum is poor. Arthroplasty was performed on the right hip.

FIG. 3-C

FIG. 3-B

D. R., 1946. Anteroposterior and lateral views taken eleven years after arthroplasty of right hip joint. Note reconstructed acetabulum with normal joint space and well-formed head. Patient has normal motion.

soever should be made to reconstruct the head. The capsule is closed over the head by several interrupted catgut sutures, and the remaining or proximal portion of the capsule about the rim of the old acetabulum is removed as completely as possible. With the limb rotated externally and adducted sharply, the site of the original hip socket can be easily identified, inspected, and palpated. With a large curette or a Doyen reamer, a capacious

FIG. 4-A

D. K., 1933. Preoperative roentgenogram. Note deformed appearance of epiphysis and poor acetabulum. Arthroplasty was performed on January 15, 1934.

FIG. 4-B

D. K., 1946. Anteroposterior view thirteen years after operation. Note how capital epiphysis has become well rounded, although not perfectly normal in appearance. Hip joint is well reconstructed at level of normal side. There is excellent range of motion.

cavity is then reamed out at the level of the original acetabulum. This point is most easily recognized by identifying the triradiate cartilage which must become the floor of the reconstructed acetabulum. (If the case is a unilateral dislocation, the site of the acetabulum can also be judged roughly by identifying the level of the tip of the greater trochanter or the anterior superior spine of the ilium on the normal side.) It should be pointed out that a remarkably deep acetabulum can be obtained. At this level, the innominate bone is very thick, and when this procedure is done for the first time, the operator is always surprised at the amount of bone that may safely be removed from this site.

The newly made cavity must be large and deep, and its floor must be smooth. When the curetting is finished, there should be a domed and properly sloping superior roof. With gentleness and without the use of a skid, the capsular-covered femoral head is placed deep within this newly made acetabulum, and the limb is placed in abduction of about 20 degrees. *It must be remembered at the time of the open reduction that the capsular-covered head has to be placed deep within the socket.* This may require placing the limb in marked internal rotation. If this becomes necessary, a supracondylar osteotomy with derotation should be done a few weeks later; this has been necessary a number of times, and is indicated whenever the anterior torsion of the neck of the femur appears to make internal rotation necessary. This has not seemed to have any effect on the ultimate function of the reconstructed hip joint.

FIG. 4-C

D. K., 1946. Lateral view thirteen years after operation.

No effort is made to suture or to attach to the acetabulum the capsule that covers the head, when it is placed in the newly formed acetabulum. It is believed that the outer surface of this capsule becomes attached firmly within a few weeks to the raw bony walls of the newly formed socket. The greater trochanter, with its attached muscles, is resutured into position. It has not been found necessary to transfix the greater trochanter with a bone graft; rather, a number of interrupted catgut sutures are placed in the soft cartilaginous tissues, and the cut surfaces of the greater trochanter are approximated snugly. The wound is closed in layers. With the hip in complete extension and slight abduction, a unilateral plaster spica is applied from the nipple line to the toes.

INDICATIONS FOR ARTHROPLASTY

Children Under Three Years of Age

The failures that occur following one or more careful attempts at closed reduction in children under three years of age are due mainly to two causes: First, there are a few cases in which reduction cannot be obtained by the closed method; and, second, redislocation sometimes occurs. It may be that a certain number of failures are due to the fact that the surgeon does not interpret properly the postreduction roentgenogram, and he thinks that the dislocation has been reduced when it has not. A great number of failures are due to an obvious interposition of soft tissues or to an insecure, sloping saucer-like acetabulum, or to both. Whatever the causes responsible for redislocations, a certain number of them do occur in children, and arthroplasty is considered to be indicated in such cases. However,

in these younger children, attempts at closed reduction should first be made, and arthroplasty should be reserved for those hips in which closed reduction has not been successful.

Children from Three to Ten Years of Age

In patients over the age of three, both soft-tissue changes and fundamental osseous maldevelopment make attempts at closed reduction increasingly difficult. Not only do the abductors and adductors become shortened and contracted, but the blood vessels and nerves also show accommodative changes. In addition, the auricular-like depression on the side of the ilium begins to form, and the head of the femur becomes more acorn-shaped or flattened, as it gravitates upward and backward. This displaced femoral head drags along the capsule, which becomes greatly thickened on its superior surface and assumes an hourglass appearance as it becomes elongated. The telescoping, which indicates relaxation of the soft tissues about the hip, varies somewhat in different individuals, but it usually becomes less as the child grows older and as the dislocated hip becomes bound in its position of dislocation through weight-bearing.

CONTRA-INDICATIONS FOR ARTHROPLASTY

As the first stage in the procedure advocated consists in meticulously stretching the soft tissues and producing a relaxation about the affected hip, it is obvious that the factors of age and weight-bearing will ultimately produce so much shortening of the soft-tissue components that the head of the femur cannot be pulled down opposite the acetabulum without running the risk of damaging these structures. It is difficult to limit the operation in children wholly on an age basis, for there are individual differences in soft-tissue relaxation; but from past experience, it is the opinion of the author that the operation discussed here should not be attempted in children over the age of ten for unilateral dislocations, or over the age of eight for bilateral dislocations. Although we have been able to obtain sufficient stretching during the first stage in children over ten to permit us to force the head into the acetabulum which has been reconstructed at the normal level, we have seen aseptic necrosis of the femoral head later develop in these older children. We have all observed that bone tissue within certain limits of stress and strain is a malleable,

FIG. 5-A

A. Y., 1933. Preoperative roentgenogram. Two weeks of traction was followed by the second stage of operation on May 5, 1933.

FIG. 5-C

FIG. 5-B

A. Y., 1946. Anteroposterior and lateral views thirteen years after operation. Note restoration of normal joint architecture following arthroplasty. Patient has normal function.

accommodative substance, but articular cartilage and bone undergo aseptic necrosis, if subjected to a continuous abnormal pressure. Therefore, some type of osteoplastic buttress or a shelf operation is more desirable in older children.

POSTOPERATIVE CARE

When the hip is taken out of plaster at the end of four weeks and active and passive motion in bed is begun with the limb suspended, the simple expedient of keeping a pillow between the limbs to retain abduction of 10 to 20 degrees on the affected side has been found adequate to prevent any danger of redislocation. This complication has not occurred in any of our series, but if, upon removal of the plaster, some effort is not made to limit adduction, this could conceivably happen. The author also favors keeping five to ten pounds of traction on the limb during the first few weeks of active movement in bed. If a therapeutic tank is available, the patient should move the limb a part of each day in this medium. The patient should be encouraged to sit up, but in order to prevent the development of any flexion contracture at the hip, the patient should be turned on his abdomen for a part of each day.

From the time the plaster is removed, particularly in the early weeks, the hip must be examined often for the effects of imbalanced muscle pull, particularly from the adductors and flexors. A good deal of functional adjustment has to be made in this reconstructed hip, as in all joints subjected to arthroplasty, and some coddling and watchful attention to details will spell success in the future progress of the hip. Not until a good range of active and passive movement in bed can be demonstrated, and any tendency to adduction and flexion has been corrected, should weight-bearing be permitted. It is difficult to give a time when weight-bearing should be begun, as this would have to be decided upon in the individual cases; but it is safe to say that a minimum of three months, and sometimes as much as six, may elapse from the time of the operation before it is wise to allow the patient to begin putting weight on the hip for limited periods during the day. During the weeks of limited weight-bearing, starting with a few minutes and gradually increasing, the hips must be carefully watched for any signs of stiffness or loss of motion. At the slightest evidence that the hip is "tightening up", the patient must return to bed. Traction for a few days will usually be sufficient to restore the previous range of motion. The use of braces to protect the hip against weight-bearing is not advocated; and only occasionally is a child found cooperative enough to be allowed to be up on crutches in less than three months, to bear weight on the normal side, and to swing the affected hip.

The roentgenograms shown represent five of the early cases which have been followed for many years. They demonstrate that the normal bony architecture of the hip has been restored.

A moving picture shown by the author at the Academy meeting demonstrated these children, ten to thirteen years after operation, walking without a limp and with an excellent range of active and passive movement.

CONCLUSIONS

From this follow-up study of ten to thirteen years, the following conclusions have been reached:

1. This two-stage procedure in the younger age group is permanently effective in providing accurate reduction, stability, and an excellent range of mobility.

2. Careful attention to details must be employed not only in the first and second stages, but also in the early part of the postoperative care.

3. The results have been better with the unilateral than with the bilateral case.

4. The procedure is not to be employed in children beyond the age of ten, while the best results have been obtained in children under eight years of age.

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DISCUSSION

DR. C. H. CREGO, JR., ST. LOUIS, MISSOURI: It is most difficult to evaluate fairly the results obtained in an operative procedure with which one has had no personal experience. I wish, therefore, to confine my remarks largely to a recapitulation or a restatement of certain basic principles in the present-day treatment of early posterior congenital dislocation of the hip, which have been brought out and emphasized by Dr. Colonna in all of his papers on the particular operation described today.

I am sure we are all agreed that it is in the patient who has not passed the age of six or seven that we can hope for results which approximate normalcy. Even in this group of cases, however, there have been in the past all too many poor results and complete failures from the old, time-honored classical methods of treatment.

What, then, are the basic principles of modern treatment, upon which depend our hope of obtaining more successful anatomical, physiological, and functional end results?

Foremost, in my opinion, is the fundamental fact that the reduction itself should in all instances be accomplished without the use of any force whatever. This, of course, implies the use of preliminary traction of one kind or another. Dr. Colonna considers traction to be a highly important part of his procedure, and I'm sure he will agree that it is an important part of any procedure which aims at reduction without trauma.

This preliminary traction, to be effective, should be sufficient to pull the head down completely, opposite the lower half of the acetabulum; and it should be maintained long enough to prevent recontraction of the soft parts, after the actual reduction has been effected. Only in this way can we completely eliminate not only the trauma incident to the reduction, but also the trauma of the intra-articular pressure following reduction.

I prefer to use skeletal traction in patients eighteen months of age and over, because I have not been able to do an adequate job with any of the various forms of skin traction. Even with skeletal traction, it is frequently necessary to tenotomize the adductors and the hip flexors, before the head can be pulled down completely.

Having been successful in placing the head into the acetabulum without trauma, we are now confronted, in the majority of cases, with developmental defects in the acetabulum which must be corrected. To be content with reduction alone and to leave a shallow acetabulum with a more or less vertical and defective roof, on the assumption that the acetabulum will deepen and reshape itself, is to court certain disaster.

This brings us to the second basic principle,—namely, that if an acetabulum is inadequate, it must in some way be made at least to approach normal. Dr. Colonna has realized this fact, and the procedure under discussion was devised to produce a socket of sufficient size and depth to hold the head adequately in place, and at the same time to preserve motion by the interposition of the capsule between the articular surface of the head and the raw surface of the newly formed socket. You have seen the roentgenograms and the moving pictures of a few of his older cases. That the results are good in the cases shown, there can be no doubt. What will eventually happen to them, no one can predict; but there is no true joint surface on the acetabular side, and for this reason traumatic arthritis may develop later.

The only other alternative in an attempt to produce depth and to restore contour to the inadequate acetabulum is that of acetabular reconstruction. To achieve this, the vertical roof of the acetabulum is turned down and reformed, so as to approach its normal contour; then this iliac bone is packed in firmly above the newly formed roof. This is not a true shelf operation, and should not be considered as such. This particular procedure has the advantage of preserving normal cartilage on the acetabular side of the joint and, to my mind, is more sound physiologically than the arthroplasty.

This brings us to the third and last basic principle,—namely, the correction of the so-called anteversion or femoral torsion. If this deformity exists in any appreciable degree, it should be corrected. It will not correct itself any more than an inadequate acetabulum will correct itself. If left uncorrected, we can expect the head to become redislocated in an anterior direction and eventually to drift upward. Dr. Colonna has not mentioned this phase of treatment, and I would like to know his ideas on the subject.

DR. C. R. ROUNTREE, OKLAHOMA CITY, OKLAHOMA: We believe that the success of the operation which Dr. Colonna has so clearly described depends, first, upon a careful selection of the patients to be operated upon and, second, upon the technical skill of the operator, plus careful preoperative and postoperative management.

A study has been made of thirteen patients operated upon at the Oklahoma Hospital for Crippled Children during the years 1938 to 1941. In ten patients, the dislocation was unilateral; and in three cases, bilateral dislocations were present.

Six patients were from two to seven years of age. Seven patients were from seven to eleven years of age. Only one patient with a bilateral dislocation was subjected to an arthroplasty of each hip. In every instance, a period of preliminary traction and stretching of the soft tissues about the hip was carried out. This was continued until the head of the femur was opposite the level of the acetabulum, or as near that point as possible.

A determination of the final results showed three cases (one, a child two years old; one, seven years; and one, eight years of age) which could be classified as excellent results. These patients had no limitation of motion in the hip, no pain, arthritic changes, or shortening, and the hip was stable.

One patient had 10 degrees of limitation of complete extension, but a full range of motion in other directions. No arthritic changes were present, and the hip was stable with one-half inch of shortening. This was considered a good result.

Two cases with some contracture and moderate limitation of motion of the joint, but with no pain or arthritic changes and no shortening, were considered fair results. In six cases, the results were classified as poor. All of these patients were in the older age group,—from eight to eleven years. Arthritic changes, stiffness of the hip, and contractures of some degree were present in all cases. Pain was also a predominant symptom. One patient, aged five, died as a result of shock, following the operation.

This procedure is not usually indicated in children above the age of eight years, or in those cases in which there is difficulty in pulling the head down to the level of the acetabulum.

I believe that the following factors are essential to a successful result:

First, a patient in the proper age group, with a unilateral dislocation.

Second, the reconstruction of a large, well-formed acetabulum.

Third, looseness of the capsule over the head of the femur.

Fourth, complete relaxation of the soft tissues about the hip, so that the head can be replaced in the newly formed acetabulum without tension.

Fifth, careful attention to the details of preoperative and postoperative management.

In no case in which this procedure was carried out, regardless of the final result, was there a redislocation of the hip. We believe, therefore, that this procedure is useful, and that excellent results can be obtained when the prerequisites listed are present.

DR. PAUL C. COLONNA, PHILADELPHIA, PENNSYLVANIA (closing): I think this group should be aware of the difficulties which have been encountered in the cases in which the operation is not applicable. It is very foolish to think that this operation is the answer for all congenital hip problems. It is very useful in obtaining stability and restoration of the normal joint architecture within certain age limits.

The point which Dr. Crego brings up—that we cannot see the ultimate result today—is perfectly true. When I first started on this, in 1930, the comment was made: "Wait a little bit, and we shall see." We have presented five cases today, in each of which the operation was performed ten or more years ago; and I hope that I can present these same cases again in another ten years. I think that the procedure is of great value within the age limits prescribed.

If a member presents a new procedure, he should present the end results five or ten years later; and if he has given up the procedure, we should know it. If he has found it successful, we should also know it.

METACARPAL RECONSTRUCTION*

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Severe injuries of the hand are frequently complicated by massive metacarpal defects, which can be corrected only by bone-grafting. The goal of reconstructive surgery of the hand is a restoration of function, and to this end an orderly surgical program should be outlined before any definitive reconstructive procedures are attempted. Obviously, if all the component parts of a digit are severely damaged, an amputation is usually indicated. Frequently, other fingers may already have been amputated; and it is, therefore, necessary in these cases to carry out reconstruction procedures, however prolonged, in order to preserve what remains of the hand (Fig. 1).

Prior to correction of the existing bone defects, it is essential to have good skin and subcutaneous tissue on the dorsum of the hand. The time expended in obtaining skin

FIG. 1

FIG. 2

Fig. 1: Loss of the ring finger with destructive fractures of the second and third metacarpals, bridged by tibial bone grafts. The proximal phalanx of the middle finger has been fused to the graft. Skilled function is possible.

Fig. 2: Transposed index finger for complete loss of thumb. A bone graft, fixed with Kirschner wire, holds the digit in a functional position.

coverage by abdominal pedicle flap or tube is well worth the effort, for the subcutaneous fat thus obtained is invaluable in forming a bed for tendon function and in filling the defects left by scar excision.

The general principles obtaining for grafts of the larger bones are also applicable to grafts of the metacarpals.[1] However, because of their small size, fixation by plate or screws is usually impractical and must be compensated for by more attention to the finer details of what Bunnell calls "bone carpentry". In general, the success of the operation is in direct proportion to the accuracy with which the graft has been fitted to the recipient metacarpal or carpal fragments. Additional fixation, when desired, can be obtained by the use of stainless-steel wire or pins, which can be transfixed into adjacent uninvolved

* Read before the American Society for Surgery of the Hand, Chicago, Illinois, January 24, 1947.

FIG. 3-A

FIG. 3-B

FIG. 4

Fig. 3-A: Massive defect involving the first, second, and third metacarpals.

Fig. 3-B: Restoration of metacarpals with doweled tibial grafts. Proximal ends of graft are embedded into carpal bones. Free tendon grafts restored extension to the thumb and fingers. The thumb can be pinched against the index finger and middle finger. The bone-grafting was done in two stages.

Fig. 4: Shows complete loss of the distal three fourths of the second and third metacarpals, with bone grafts stabilizing the proximal phalanges in flexion of 30 degrees.

FIG. 5-A

Multiple metacarpal defects are shown.

FIG. 5-B

In early postoperative views, note restoration of the longitudinal palmar arch and the functional position of the thumb.

FIG. 5-C

FIG. 5-D

Showing early functional results in same case.

Fig. 6-A

FIG. 6-B

FIG. 6-C

FIG. 6-D

Fig. 6-A: Roentgenogram shows destructive metacarpal fracture with shortened finger and hyperextended metacarpophalangeal joint.

Fig. 6-B: Postoperative view shows some gain in finger length and stabilization of the metacarpal head.

Figs. 6-C and 6-D: Postoperative function in same patient.

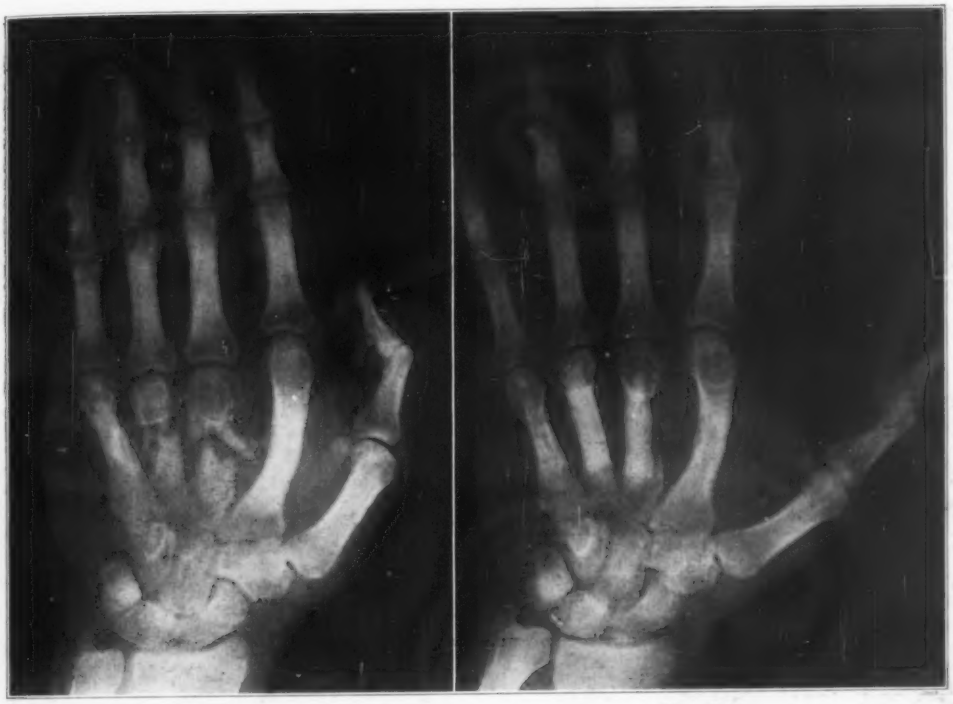

FIG. 7-A FIG. 7-B

FIG. 7-C FIG. 7-D FIG. 7-E

Figs. 7-A and 7-B: Preoperative and postoperative views show metacarpal reconstruction.

Fig. 7-C: The metacarpal heads have been stabilized through bone-grafting, but contracted collateral ligaments prevent flexion of the metacarpophalangeal joints.

Figs. 7-D and 7-E: Range of motion following excision of collateral ligaments.

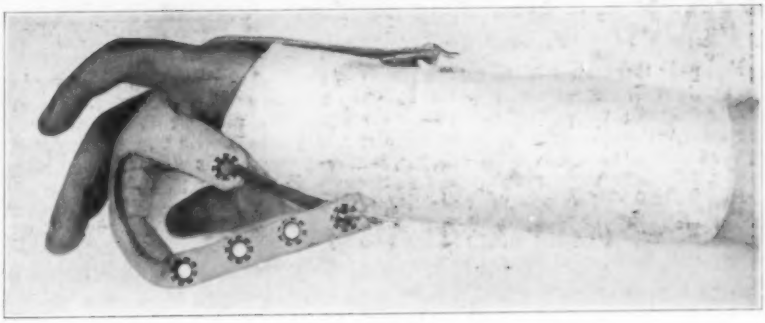

FIG. 8

Fig. 8: Traction splint used for overcoming a tight extensor mechanism. The progressive pull is directed toward the tubercle of the navicular.

FIG. 9-A

FIG. 9-B

FIG. 9-C

FIG. 9-D

Fig. 9-A: Shows loss of all but the head of the first metacarpal, resulting in a useless thumb.
Fig. 9-B: The graft was inserted into the carpus and the adjacent metacarpal base. Postoperative roentgenogram, taken two years after bone-grafting, shows complete union. Patient can extend fully the interphalangeal and metacarpophalangeal joints of the thumb, and the thumb can be pinched against the index finger, middle finger, and ring finger. His work is assembling typewriters.
Fig. 9-C: Lateral view illustrates functional position of the thumb.
Fig. 9-D: Function possible following a tendon graft for loss of the extensor pollicis longus.

metacarpal or carpal bones (Fig. 2). If only the head of the metacarpal remains, it can be stabilized by extending the graft into the carpus (Figs. 3-A and 3-B); if only the base remains and the digit must be preserved, the graft can be fused to the proximal phalanx at 30 degrees of flexion (Fig. 4). In cases of multiple metacarpal defects, multiple bone grafts usually can be placed in one operation (Figs. 5-A, 5-B, 5-C, and 5-D.)

FIG. 10-A

FIG. 10-B FIG. 10-C FIG. 10-D

Fig. 10-A: Photograph showing compound fracture-dislocation of the first metacarpophalangeal joint, with loss of the flexor pollicis longus.

Figs. 10-B, 10-C, and 10-D: Thumb function following fusion of the metacarpophalangeal joint and free flexor-tendon graft. Fusion of the thumb metacarpophalangeal joint in flexion of from 20 to 30 degrees produces little disability.

FIG. 11

a: Metacarpal fracture, showing hyperextension deformity of the metacarpophalangeal joint and contracted collateral ligament. Dotted lines indicate preparation of the fragments to receive the graft.

b: Tibial graft has been shaped for insertion.

c: Illustrates various methods for bridging metacarpal defects. Note that, if the head and neck are present, the dowel is used; whereas, if only the head remains, a blunt end of the graft is impaled into the cancellous bone of the head. The distal metacarpal fragment or the proximal phalanx of the finger is adjusted so that, on flexion, the tip of the finger points to the tubercle of the navicular.

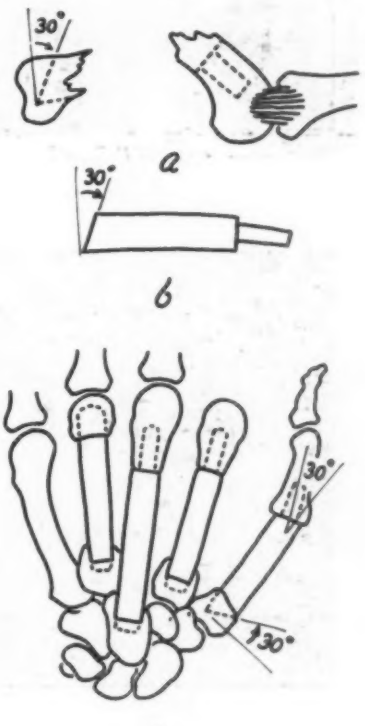

FIG. 11

The shortened finger with a stiff, hyperextended metacarpophalangeal joint (Figs. 6-A, 6-B, 6-C, and 6-D), which so frequently is a complication of a long-standing, badly comminuted metacarpal fracture[3], requires preliminary stabilization of the distal fragment with a bone graft, if useful function is to be restored. In cases in which joint flexion is not regained after bone-grafting, excision of the contracted collateral ligaments and lysis of the extensor tendon may be necessary (Figs. 7-A, 7-B, 7-C, 7-D, and 7-E). Excision of the collateral ligaments can be done at the time of grafting, if a sufficiently large distal metacarpal fragment is present. Once the metacarpal head has been stabilized, however, traction on the finger alone (Fig. 8) may restore flexion.

Disability resulting from loss of the first metacarpal is much greater than that occurring in the case of the other metacarpals. If the proximal portion of this metacarpal has been destroyed, the distal fragment can be fused to the carpus; and, if the thumb is placed and maintained in a functional position, a useful digit will result (Figs. 9-A, 9-B, 9-C, and 9-D). If the injury should involve the distal portion of this metacarpal with extension into the metacarpophalangeal joint, a fusion of the joint at approximately 30 degrees of flexion is recommended (Figs. 10-A, 10-B, 10-C, and 10-D).

Early immobilization of the injured hand in the position of function is of great value in the later procedures of reconstructive surgery. Following wound healing, every effort

FIG. 12-A

Illustrative case, showing the method of repair.
Fig. 12-A: Preparation of fragments for tibial-bone graft.

FIG. 12-B

Hyperextended metacarpophalangeal joint being flexed. Excision of collateral ligaments is not necessary in this case.

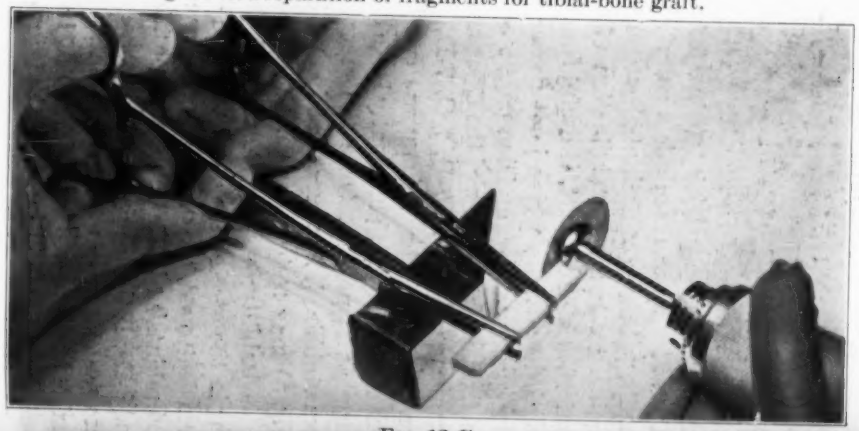

FIG. 12-C

Forming dowel with circular saw.

FIG. 12-D

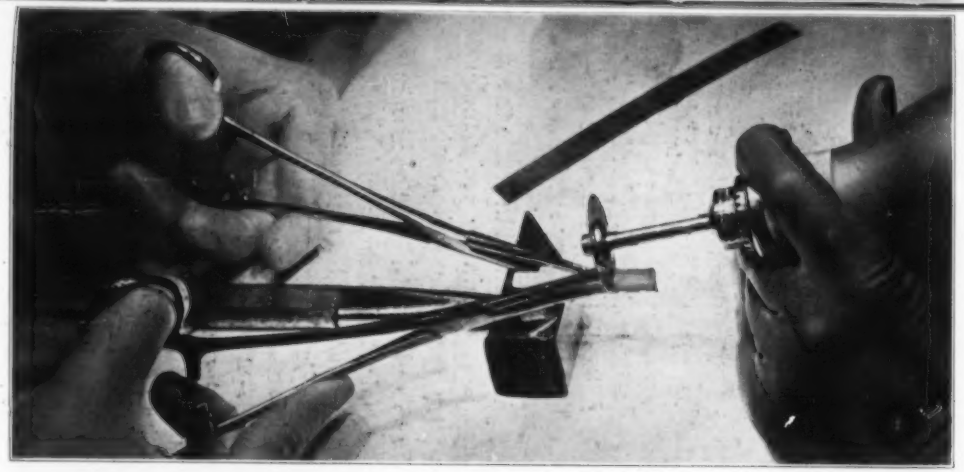

FIG. 12-E

Graft being cut to proper length, which is determined by measuring defect with traction on finger.

FIG. 12-G

Base of graft is being pressed into recess of proximal metacarpal fragment.

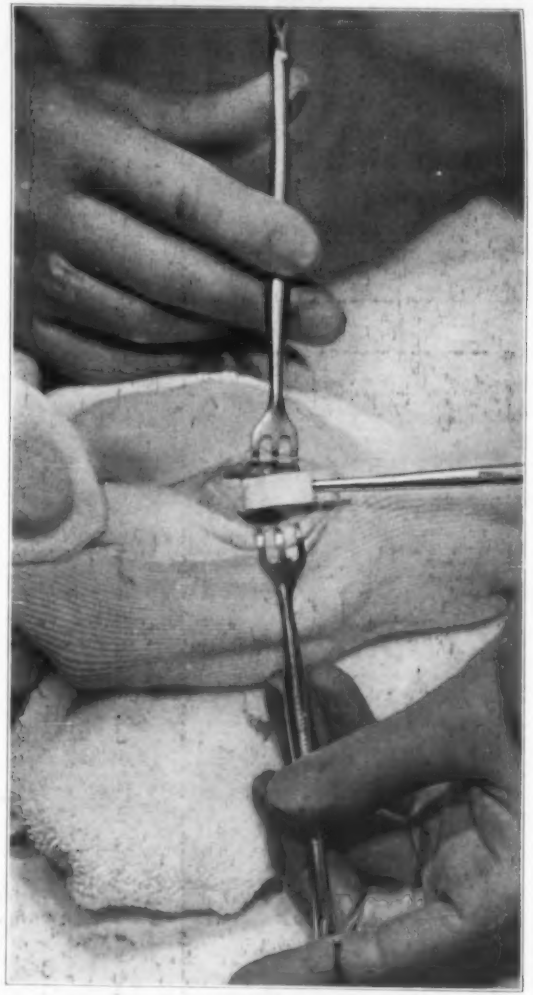

FIG. 12-F

Doweled end of graft being inserted into medullary canal of distal metacarpal fragment.

FIG. 12-H

FIG. 12-I

FIG. 13

Fig. 12-H: Roentgenogram of destructive metacarpal fracture, showing typical deformity.

Fig. 12-I: Postoperative roentgenogram, showing moderate gain in length.

Fig. 13: Plaster immobilization of grafted metacarpal, permitting freedom of intact structures. The finger is flexed to 30 degrees at the metacarpophalangeal joint. Active flexion and extension of the interphalangeal joints are possible.

should be made to maintain by early mobilization whatever function remains, for only with all the intact structures functioning satisfactorily can the injured portion of the hand be evaluated properly and the reconstruction program be outlined.

OPERATIVE TECHNIQUE

Exposure of the metacarpal to be grafted is gained through either a longitudinal or a curved incision, depending upon the existing scars and the nature of the resurfaced defect. All scar tissue is dissected from the extensor tendons, care being taken to preserve intact paratenon. The fibrous tissue between the metacarpal fragments is dissected *en bloc*, so that a bed of soft tissue is exposed; it is then possible to regain by traction most of the normal finger length. In most cases, for good results, the proximal fragment must be sacrificed as far as its base, where it is recessed with the osteotome at an angle of approximately 30 degrees (Fig. 11,*a*). The distal fragment is cut transversely with the circular saw or rongeur, and the medullary canal is opened to receive the doweled end of the graft. With traction on the finger, the defect between the metacarpal fragments is measured carefully

FIG. 14-A

FIG. 14-B

Fig. 14-A: Shows destructive fracture of the fourth metacarpal.
Fig. 14-B: Photograph taken three months after operation shows union of graft to metacarpal fragments. Excellent function with full flexion at the metacarpophalangeal joint resulted.

FIG. 15-A

FIG. 15-B

Fig. 15-A: Malunited fracture of metacarpal of index finger, with volar angulation of distal fragment and internal rotation of finger.
Fig. 15-B: Showing correction by bone graft.

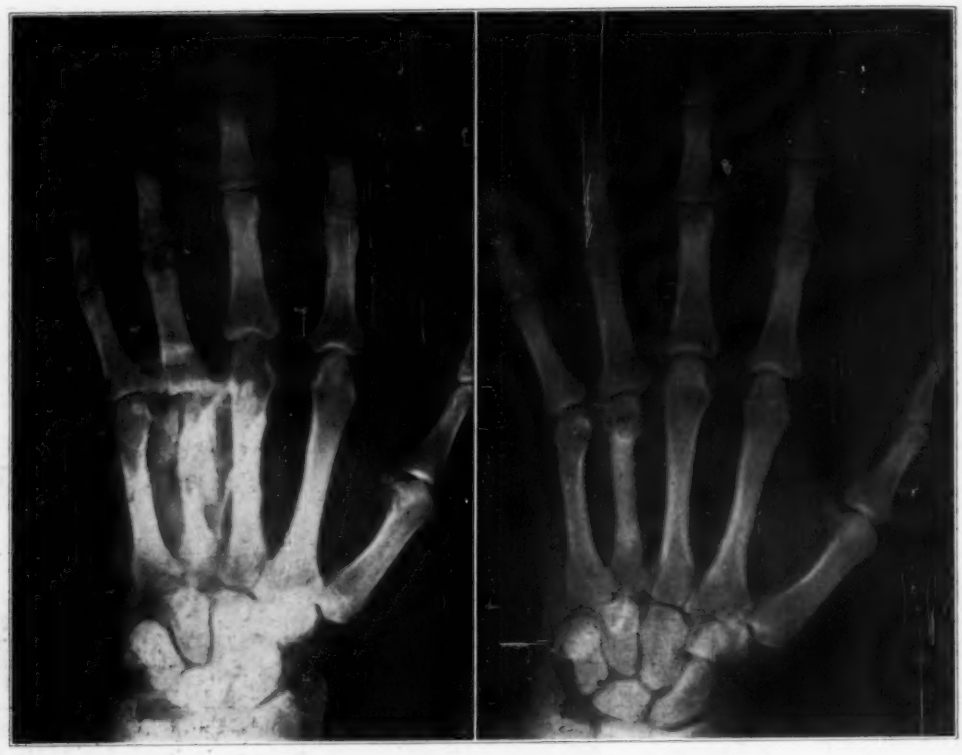

FIG. 16-A FIG. 16-B

Fig. 16-A: Destructive metacarpal fracture of ring finger.
Fig. 16-B: Result following bone-grafting.

FIG. 17-A

FIG. 17-B

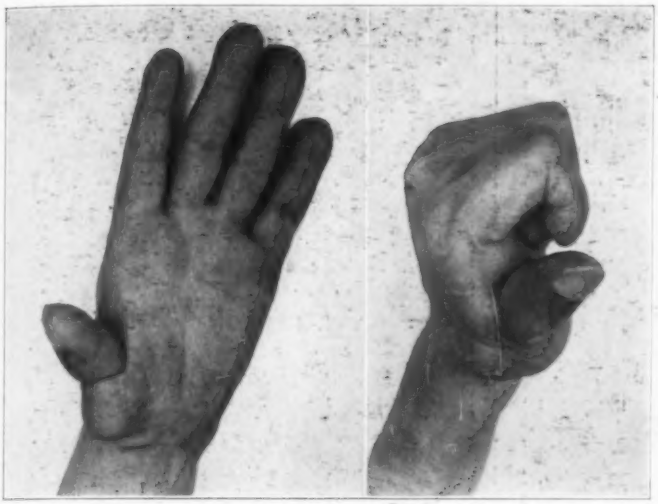

FIG. 17-C

FIG. 17-D

FIG. 17-E

FIG. 17-F

FIG. 17-G

FIG. 17-H

Fig. 17-A: Complete destruction of thumb metacarpal.
Fig. 17-B: Roentgenogram of iliac-bone graft between greater multangular and proximal phalanx, with thumb in functional position.
Figs. 17-C and 17-D: Preoperative photographs.
Figs. 17-E, 17-F, 17-G, and 17-H: After operation, the thumb can be opposed by the index and middle fingers.

and a graft, measuring at least one-half inch longer than the estimated defect, is taken from the upper end of the tibia. A dowel is fashioned at one end of the graft with the circular saw. The other end is cut obliquely at 30 degrees. The doweled end of the graft is inserted into the medullary cavity of the distal fragment, and the proximal end of the graft is pressed into the metacarpal or carpal recess. Compression of the graft between the two fragments is sufficient to hold it in place at the base (Fig. 11, *c*). The periosteal sleeve, if present, and the soft tissues are carefully closed over the graft with fine silk or cotton sutures. The various steps in the operative procedure are illustrated in Figures 12-A to 12-G, inclusive. Following operation, a plaster-of-Paris cast is applied, which extends to the proximal interphalangeal joints, with the hand being maintained in the position of function. This cast is immediately split to facilitate postoperative decompression. On

FIG. 18-A

FIG. 18-B

Fig. 18-A: Shows loss of distal thumb metacarpal, with joint involvement.
Fig. 18-B: Defect bridged by graft, uniting the proximal metacarpal fragment to the phalanx. Function of long extensor and flexor tendons has been preserved.

FIG. 19-A

FIG. 19-B

Utilization of proximal and middle phalanges of functionless fifth digit for bone bridge between the carpus and proximal phalanx of ring finger. The transplanted joint flexes through a useful range of 45 degrees. Extension of ring finger gained through free tendon graft.

about the twelfth day a new cast is applied (Fig. 13), immobilizing only the grafted metacarpal and the proximal phalanx. A period of two months is required before good union is present (Figs. 14-A, 14-B, 15-A, 15-B, 16-A, 16-B, 17-A to 17-H, 18-A, and 18-B).

Penicillin is given routinely for eight days after operation, because all of these patients have had compound fractures, either potentially infected or previously complicated by osteomyelitis.

To date, forty-four patients have had metacarpal grafting with a total of fifty-six individual grafts. As many as three grafts have been placed at one time. Individual grafts have been used for each metacarpal. Clinical union and callus formation, with loss of the sharp line of demarcation between the graft and the fragments, have resulted during the third month in all grafts except three (two small grafts were absorbed, and one failed to unite to an atrophic third metacarpal head which was angulated volarward). It has been possible in several cases to utilize bone from an amputated finger to restore a metacarpal (Figs. 19-A and 19-B).

CONCLUSIONS

In selected cases of metacarpal fractures with loss of bone substance, bone-grafting is a worth-while procedure for relieving pain at the fracture site and for restoring the normal architecture, strength, and function of the hand.

NOTE: The author wishes to acknowledge the kind suggestions made for the preparation of this paper by William J. Tobin, M.D.

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PRIMARY ARTERIAL INJURY COMPLICATING EXTREMITY FRACTURES

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Experience with war wounds has taught surgeons the necessity of repairing damaged arteries early, in order to re-establish and maintain circulation in a salvageable extremity. Fractures and crushing injuries seen in civilian practice are also frequently complicated by severe damage to soft structures.

Injury to main arteries in certain areas means loss of the extremity, unless repair is prompt and successful. If traumatized tissues have their blood supply decreased by vasospasm, shock, or direct injury to an artery, infection may develop in lacerations and compound-fracture wounds, and tissue repair be decelerated. Chemotherapy is only effective in direct proportion to the blood supply.

Shock can be combatted by blood transfusions and control of hemorrhage. Vasospasm can be controlled by sympathetic novocain block or by one of the newer drugs, such as tetra-ethyl-ammonium chloride, unless shock is present. Lacerated or traumatized arteries with thrombi must be treated promptly by surgery, if a main vessel is involved; otherwise, gangrene will develop, and a potentially useful extremity will be lost.

Accidents resulting from our present high-speed transportation and accelerated industry produce severe crushing injuries and compound fractures. Extensive damage to the soft tissues may result from the direct blow, as well as from wide displacement of the fragments of fractured bones.

It is axiomatic that preservation or re-establishment of the circulation to the extremity must take precedence over any attempt to obtain a satisfactory reduction, fixation, or immobilization of the fractures. It, therefore, behooves the surgeon treating fractures to be constantly on the alert for any impairment of circulation distal to the fracture site; in such cases there is no greater emergency than a lacerated or thrombosed main vessel.

It is our purpose to present four typical cases of arterial injury associated with fractures, to discuss their diagnosis and treatment, and to emphasize the necessity for prompt attention in such instances. Case 4 is unusual in that anastomosis was obtained with a tantalum tube by non-suture technique.

Case 1, L. M. (No. 428887). This patient was admitted to the Emergency Department on October 7, 1944, suffering from a compound, comminuted fracture of the right femur, which occurred when she was struck by a truck. On admission, she complained of pain in the leg and numbness of the right foot. A tourniquet was in place. Roentgenograms showed a comminuted fracture at the junction of the middle and lower thirds of the right femur with considerable posterior displacement of the distal fragments (Fig. 1). There was no pulsation of the vessels of the foot. She was taken to the operating room and treated for shock by transfusion. Two compound fracture wounds were found on the posteromedial aspect of the thigh. These were cleaned, lavaged, and debrided. They were then connected by a small incision for investigation of the fracture site; this exposed the great vessels. One of the comminuted fragments was found to have rotated posteriorly and impinged directly on the femoral artery. At first glance, the artery appeared to be intact, but closer investigation revealed a bulbous swelling at the proximal portion of the wound, followed by a thinning out of the substance of the vessel and then, about one and a half inches distally, the normal thickness of the vessel could again be palpated. The fragments were manipulated out of the way, and a linear incision was made in the artery at the site of the injury. The adventitia and media were incised, and the intima was found to be completely ruptured and separated for a distance of about one and a half inches. Distally there was an extensive longitudinal laceration of the intima. Bulldog clamps were applied to the distal and proximal portions of the artery. The knee was flexed to relieve the tension of the vessel. A red thrombus was removed from the proximal end. The bulldog clamps were released, and the tourniquet was removed. Blood flowed freely. The clamps were then re-applied. The intima was sutured with fine artery silk, and the other layers

were similarly approximated. The suture line held well when the bulldog clamps were removed. The pulsation extended well below the suture line. Because of the extensive nature of the compound wound, it was felt inadvisable to heparinize this patient. She was in moderate shock in spite of her transfusions. The wounds were, therefore, closed with chromic catgut. To control the fragments, Steinmann pins were inserted through the upper third of the tibia and the os calcis for traction. A Thomas splint was applied.

No arterial pulsation was ever obtained in the foot. The foot remained cold, and mummification set in within four days. Permission for amputation was denied until October 23, 1944, when a mid-thigh amputation was done. Convalescence was uneventful. The patient was discharged from the Hospital on November 11, 1944. She was followed in the Out-Patient Department until May 14, 1945, at which time she was walking with a prosthesis.

This case illustrates the problems of treatment before the advent of the metallic tube. A severe compound fracture was complicated by laceration of the main artery by a displaced bone fragment and extensive damage to the other soft structures. The femur was badly comminuted, and very active bleeding from the medullary cavity took place when the tourniquet was released. This hemorrhage, plus scattered minor bleeding, made the use of heparin seem inadvisable. Yet we are convinced that, by preventing postoperative thrombosis, heparin might have made the anastomosis successful.

Case 2, S. K. (No. 34878). This patient, having been struck by a motor car, was admitted on February 20, 1946, to the Emergency Department, with comminuted, intra-articular fractures of the upper third of the left tibia and fibula. The extremity had been struck from the rear by the car bumper. There was also a laceration of the scalp and cerebral concussion. The scalp laceration was sutured. The left leg, distal to the fracture site, rapidly became swollen. Extensive bleb formation took place. The pulsation of the dorsalis pedis and the posterior tibial arteries could not be felt. Motor and sensory paralysis existed below the fracture site.

Roentgenograms failed to show any displaced fragments which might have lacerated the nerves or vessels (Fig. 2). During an hour's observation, swelling of the leg increased in spite of elevation of the leg, and a mass, which seemed to pulsate, was noted in the popliteal space. It was, therefore, deemed advisable to explore the popliteal region for a lacerated artery.

A linear incision, about eight inches in length, was made in the popliteal region, with a tourniquet in place. The tibial nerve was encountered and was found to be hemorrhagic for a distance of several inches. The artery and vein were isolated and were followed between the heads of the gastrocnemius. The vessels were seen to pass into the torn soleus, and a large hematoma was found just beneath it. The vein was completely ruptured. The popliteal artery was isolated, and the posterior tibial artery was found torn at the bifurcation. Available Vitallium tubes were found to be too large for vessels of this size. It was impossible to suture the vessels, because of the type of laceration. The posterior tibial artery and vein were, therefore, ligated. The defect in the popliteal artery was sutured with fine artery silk. The tourniquet was then released and the suture line seemed to hold well. Two cubic centimeters of heparin was then injected into the artery, proximal and distal to the traumatized area. The vessel was seen to pulsate distal to the area of repair. Because of the severe oedema, the wound could not be closed. A vaselin dressing was applied, and the extremity was splinted.

After the patient was returned from the operating room, heparin was started. The toes soon became cyanotic, and the cyanosis increased the following day. A left lumbar sympathetic block was done without improvement in the circulation of the extremity. The next day the block was repeated, again without result. The leg became progressively gangrenous, and, on March 1, 1946, a mid-thigh amputation was done. Recovery was uneventful. The patient was discharged from the Hospital thirteen days later and was walking with a prosthesis when last seen on October 3, 1946.

Secondary thrombosis occurred in this case in spite of heparin and a sympathetic block. The arterial damage was too extensive to have been overcome, even if a metallic tube of the correct size had been available. It should be noted that, in this case, the soft-tissue damage was caused solely by the force of a crushing injury. The bone fragments were not appreciably displaced. Such injuries to arteries can occur in the absence of any fracture.

Case 3, J. H. (No. 66406). This patient was admitted to the Emergency Department on March 13, 1945, after an industrial accident. Examination revealed a severe, compound, comminuted fracture of the mid-portion of the left humerus (Fig. 3), complicated by paralysis of the ulnar nerve and absence of radial pulsation at the wrist. The man was taken directly to the operating room, where the compound fracture wound was carefully cleaned, lavaged, and debrided. Incision was then made over the medial aspect of the

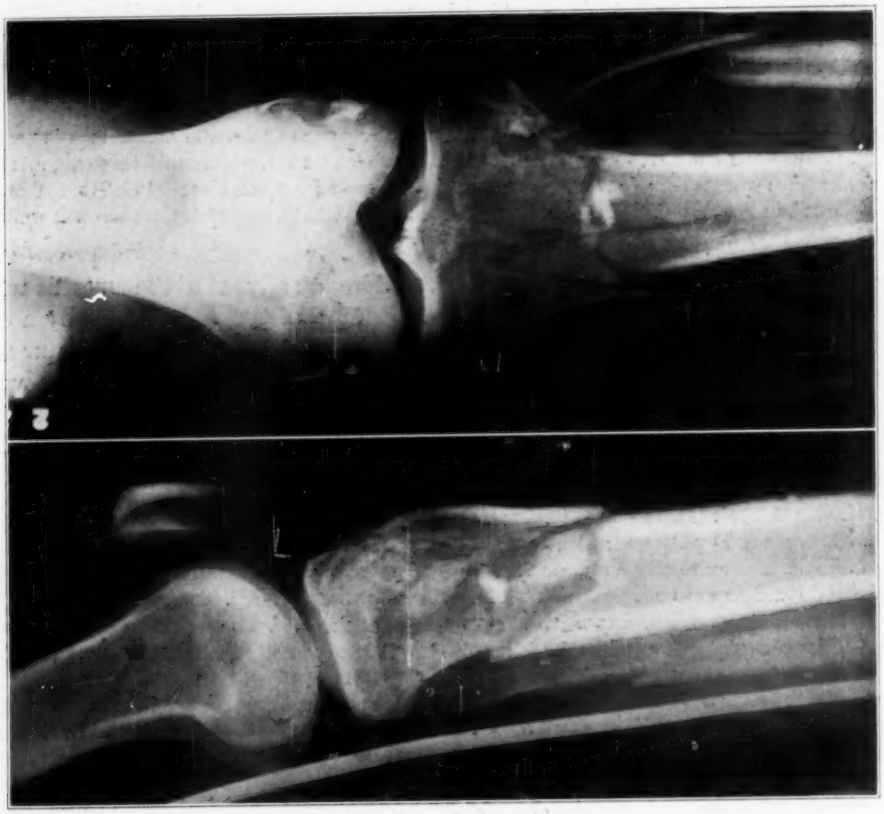

FIG. 2

Case 2. Comminuted fracture of tibia and fibula with injury to popliteal and tibial arteries.

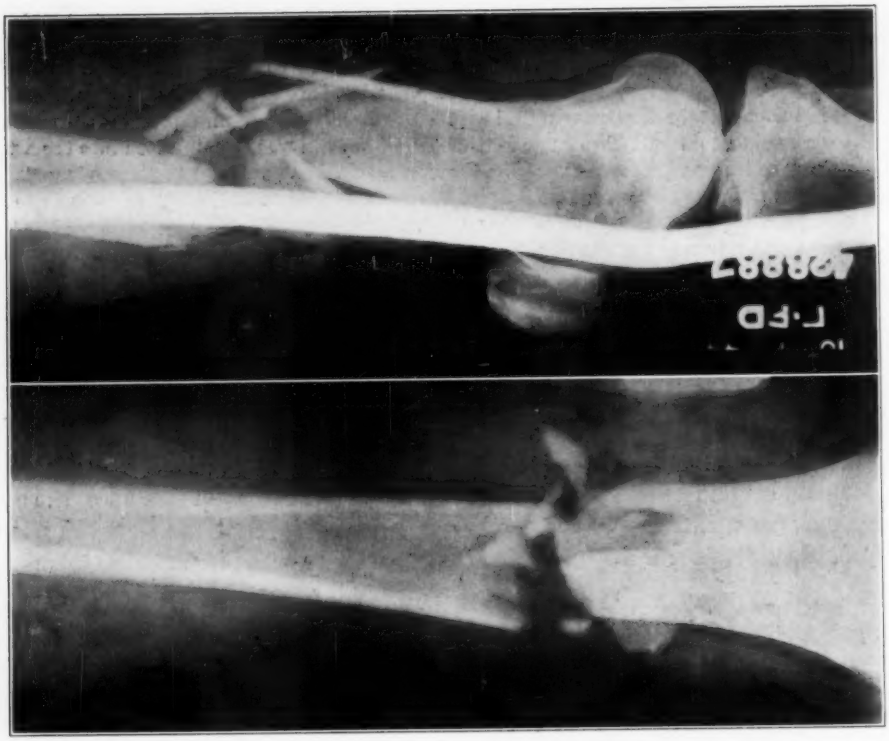

FIG. 1

Case 1. Compound, comminuted fracture of femur with extensive damage to femoral artery.

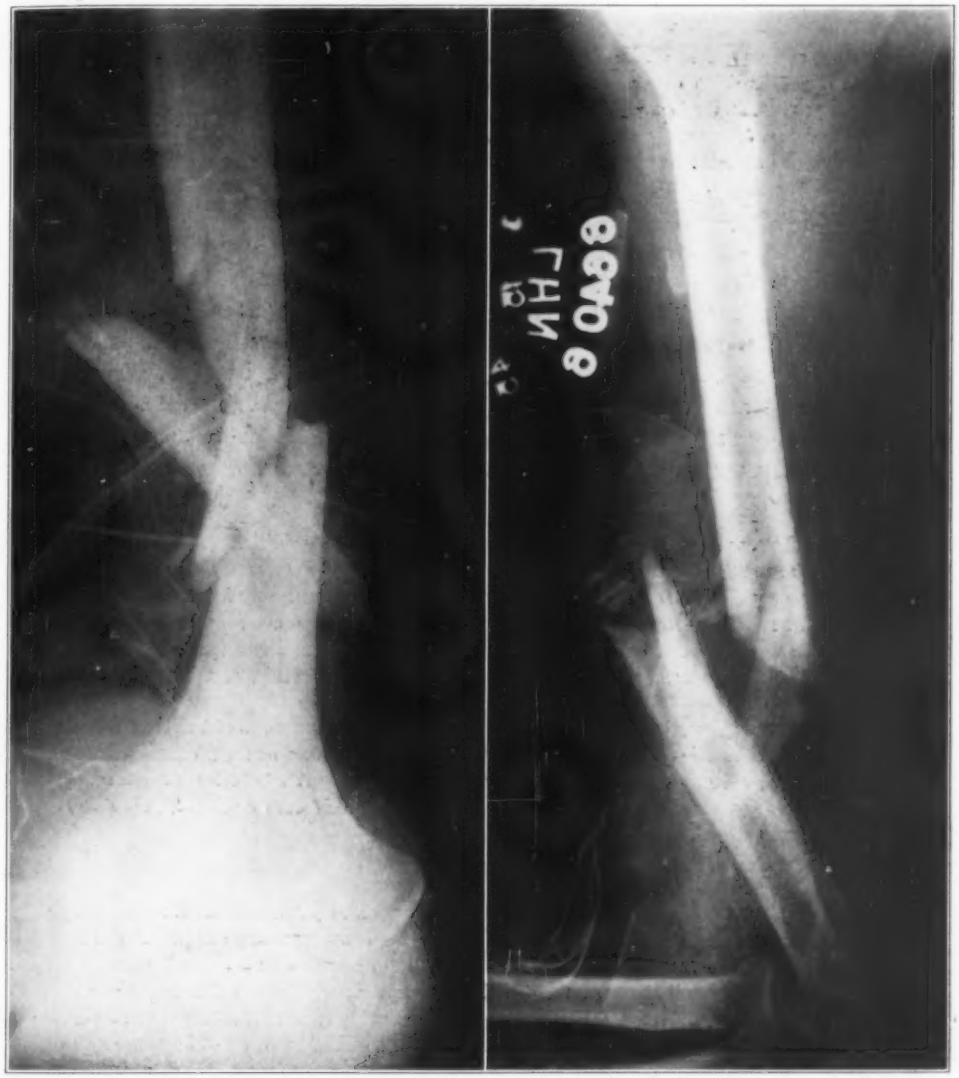

FIG. 3

Severely comminuted fracture of left humerus with injury to brachial artery.

middle third of the arm. The basilic vein was identified and retracted, as were the median and ulnar nerves. Next, the brachial artery was isolated and found to be in severe spasm throughout the entire length of the incision. One of the comminuted bone fragments was rotated and impinged directly against the vessel. A bulbous thickening of the vessel was found at the site of injury, distal to which the artery appeared to be collapsed. The artery was incised at the site of the dilatation; and a red thrombus, one inch in length, was removed. The intima was slightly torn. Blood spurted through the incision in the vessel wall. A bulldog clamp was applied. Compression of the forearm forced blood from below through the incision. The vessel was closed with artery silk, and the incision in the skin was closed with fine chromic catgut. A Kirschner wire was then inserted in the olecranon process of the ulna. Traction was applied in a Thomas arm splint after the patient was returned to his bed. A faint radial pulse could be felt after the procedure was over. The patient was heparinized for three days. The radial pulse improved and was of normal intensity.

In two weeks, the Kirschner wire was removed, and the extremity was placed in a hanging arm cast. The patient was discharged from the Hospital on April 2, 1945. Healing of the fracture took place with a moderate degree of angulation. Paralysis of the ulnar nerve persisted.

The patient was readmitted to the Hospital six months after the injury for a neurolysis of the ulnar nerve and transposition of it to the antecubital region. He was discharged one week later and followed in the Out-Patient Department. When last seen, he showed good return of the sensory and motor functions of the ulnar nerve.

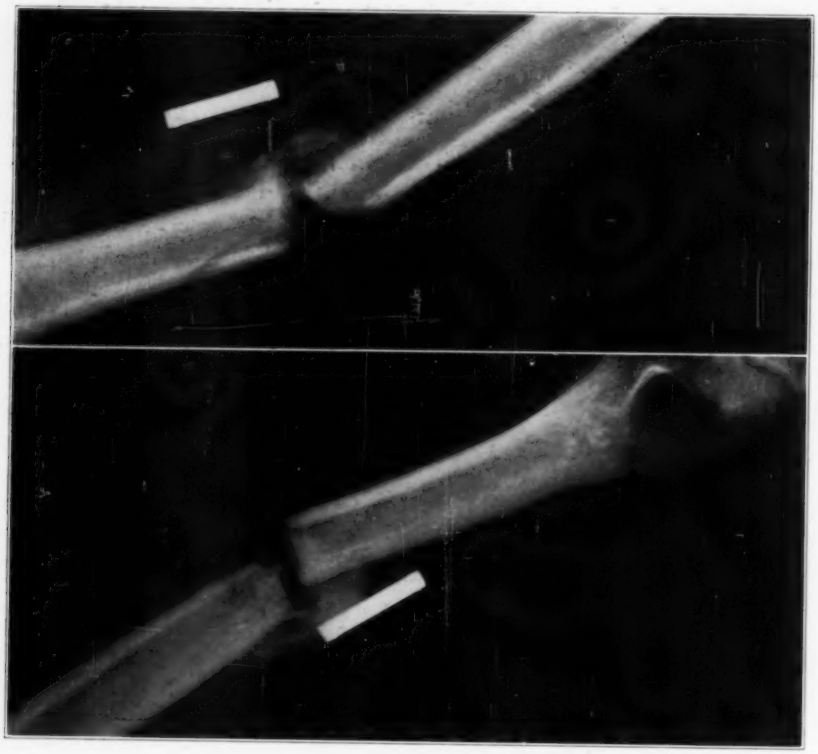

FIG. 4-B

Case 4. Postoperative roentgenogram showing tantalum tube in place.

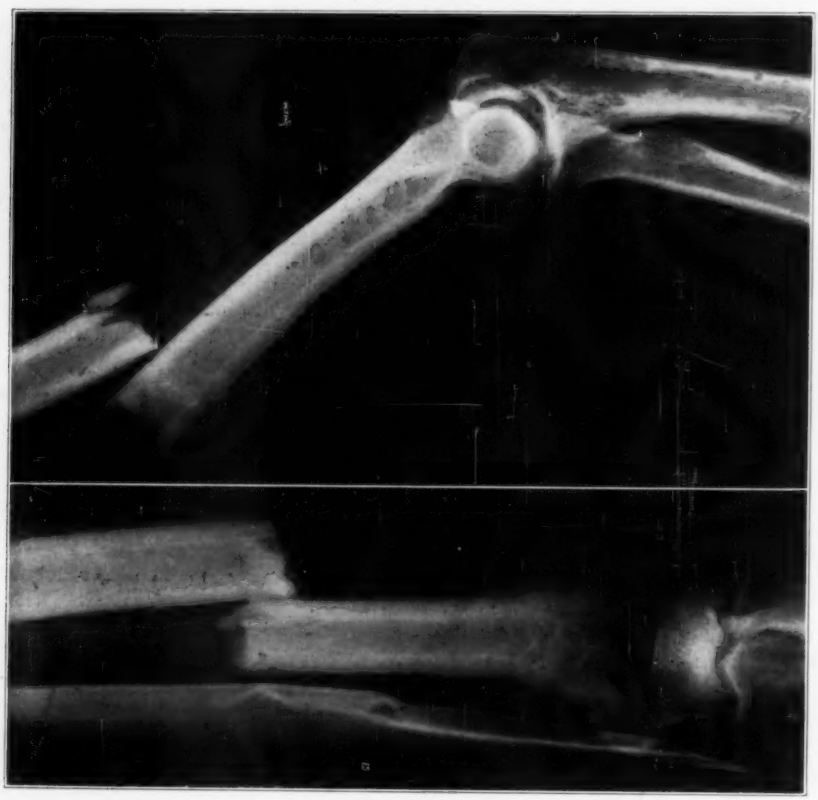

FIG. 4-A

Case 4. Simple fracture of the humerus. Brachial artery injured.

This arterial injury was one of simple compression and thrombus formation, without extensive damage to the vessel itself. Severe vasospasm was present. Removal of the thrombus, heparinization, and reduction of the fracture resulted in a satisfactory recovery in a case which might otherwise have come to amputation.

Case 4, E. H. (No. 468899). This patient was admitted on February 28, 1946, after slipping on an icy street and being struck by an automobile. She was seen in the Emergency Department about two hours after the injury, complaining bitterly of the pain and paraesthesia in the left hand, which had been present since the accident. Roentgenograms revealed a transverse fracture in the middle third of the left humerus (Fig. 4-A) and also fractures of the sixth, seventh, and eighth ribs. A compound-fracture wound was present on the posterior aspect of the arm, about three inches above the elbow. There was normal motor function in the hand and wrist. The sensory disturbance was generalized, and involved the entire hand, which was blanched and cold. No radial or ulnar pulse was obtainable. No extensive hemorrhage was noted at the fracture site.

Inasmuch as it was thought possible that one of the fragments might have compressed a vessel, the fracture was carefully reduced with fluoroscopic control. This procedure failed to improve the circulation of the hand. After a one-hour wait, a sympathetic block of the stellate ganglion was performed, which was successful as evidenced by the appearance of Horner's syndrome. This seemed to render the hand somewhat warmer, but it remained blanched and pulseless. After an interval of two hours, the circulation was still inadequate, and an exploration of the brachial artery was done.

Under pentothal-sodium anaesthesia, a ten-centimeter incision was made over the medial aspect of the upper arm at the posterior border of the biceps. There was considerable hemorrhage and evidence of trauma to the subcutaneous tissue in this region. The deep fascia had been lacerated along the medial border of the biceps, and a fragment of the fracture had extended anteriorly through the brachialis muscle and its fascia. The brachial artery was exposed for the length of the incision and isolated from the accompanying structures. An area of thrombosis, approximately one centimeter in length, was found in the artery in the mid-portion of the incision; a smaller thrombus was seen four centimeters proximal to the injury. There was evidence of spasm of the entire portion of the artery viewed. The median nerve was explored above and below the fracture site and found to be uninjured. The thrombosed region of the artery was isolated, and the surrounding tissues were packed out of the field of operation with moist gauze. Bulldog clamps were applied above and below the thrombus. A linear incision, one centimeter long, was then made over the area of thrombosis, and the clot was removed. The intimal lining of the artery was severely injured for a distance of approximately one-half centimeter on its posterior aspect. The wall of the artery was considerably thinned in this region. It was impossible to perform a direct anastomosis to eliminate the defect, and it seemed advisable to use a tantalum tube. A tube of proper diameter and length was obtained from C. R. Lam, M.D., who was using tantalum tubes in his experimental work in blood-vessel surgery on animals. The artery was transected at the site of the injury, and the injured portion of the vessel, about two centimeters in length, was excised. The smaller proximal clot was aspirated with a smooth, small cannula. The column of the artery, both proximal and distal to the injury, was heparinized. The tantalum tube was then prepared, according to the method described by Blakemore and his associates. A section of vein, of adequate diameter and length, was taken from the larger of the venae comitantes, which were in direct relation to the brachial artery. The vein was washed out immediately with heparinized saline, care being used not to injure the intima. It was threaded through the tube, and the ends were everted and secured with a fine ligature beyond the ridges in the tube. The tube was then inserted with the distal end of the vein section in the proximal end of the artery to eliminate danger of obstruction by the valves of the vein. This was easily done with very little stretching of the proximal end of the severed artery. The artery was pulled well onto the tube, and a silk ligature was placed tightly around the artery past the ridge of the tube. A fine ligature was likewise placed snugly, but not tightly, distal to the ridge. A similar procedure was carried out at the distal end, but with more difficulty, because of the smaller diameter of the artery. At this point, heparin was given intravenously, the procedure was completed, and the clamps were released. The artery was now seen to pulsate distal to the tube. The incision was closed in layers, and a posterior plaster mold was applied to the extremity for fixation.

The patient was heparinized, and the clotting time was maintained at five to six minutes. The patient was given penicillin for a period of eight days.

Immediately following the operation, the patient was in mild shock and the radial pulse could not be palpated. Two hours following the procedure, however, the hand had a normal temperature, and the pain had subsided. On the second day, palpation revealed a good radial pulse which remained strong. A hanging arm cast was applied eight days later and removed on the twenty-first postoperative day (Fig. 4-B). A good radial pulsation was present, which was watched for forty-eight hours. The patient was discharged from the Hospital on March 22, 1946. She was followed in the Out-Patient Department; satisfactory union and good circulation in the extremity developed.

As far as we can determine, this is the first case in which a tantalum tube has been used to bridge an arterial defect in the human. Vitallium tubes have been used and

reported both experimentally and clinically by Blakemore, Lord and Stefko. Further experimental work with tantalum tubes has been carried out by Lam of this institution.

The procedure used has been described by Blakemore and Lord [1] and the reader is referred to the original work for complete technical details. The pitfalls to be avoided have been discussed by the same group. They caution the surgeon to avoid the use of a tube that is too large for the artery. They also warn against a ligature which is too tight at the distal end of the tube and against injury or clot formation in the vein graft.

Tubes should be available in graduated sizes. In our opinion, nearby veins may be used at the time of the surgery, thus avoiding the necessity of "quick freezing" the tube and vein units, as suggested by other authors. It seems more reasonable to use homogenous tissue and avoid the possibility of tissue reaction.

The use of heparin has decreased markedly the danger of postoperative thrombosis. The fear of thrombosis must be balanced against the danger of hemorrhage and hematoma formation. Heparin is almost indispensable to the success of the procedure.

As far as we know, arteriography has not been done in this type of case. The value of the procedure described can be measured only by the clinical success.

DISCUSSION

These cases are presented and discussed individually to illustrate the damage that can be done to an important artery at the time a fracture occurs. The importance of early recognition of the impairment of circulation to an extremity cannot be overemphasized. Such a situation calls for emergency care.

Residents in charge of emergency admitting departments must ever be on the lookout for such cases, so that these patients will not be splinted or immobilized and sent to the ward. The next day will be too late, and amputation will be inevitable.

Case 1 is an example in which an amputation might have been avoided, if a metallic tube had been available and heparin could have been used.

Case 2 demonstrates the effect of a severe blow on an arterial tree with extensive damage, not by displaced bone fragments, but by the force of the blow itself[4].

Case 3 illustrates how easily the circulation can be impaired by localized compression of the artery with formation of a thrombus and development of vasospasm. This has been described by Cohen.

Case 4 is an example of a localized arterial injury, treated with a tantalum tube to bridge the defect. It is described in greater detail, because of the type of repair utilized.

We feel the use of heparin in these cases is of the greatest importance. In this may rest the success or failure of the operative procedure. Should hemorrhage occur—and the doctor must always watch for this—a tourniquet may be applied. Amputation may be necessary, but at least the extremity has been given a chance to re-establish circulation. Without heparin, failure of circulation is more likely, with possible amputation.

The surgery involved in arterial repair is tedious, time consuming, and extremely fatiguing for it calls for painstaking attention to details, and after the operation has been finished, there is still the fracture to treat. Regardless of the effort expended, there is a much better chance of obtaining an intact and useful extremity.

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CARTILAGE AND CHONDROITIN SULPHATE

I. The Physiological Role of Chondroitin Sulphate in Cartilage *

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In spite of recent contributions regarding the composition, molecular structure, and protein reactions of chondroitin-sulphuric acid, our knowledge of the biological function of this substance in normal cartilage is still incomplete. Morphologists have hitherto avoided discussing this question; but the rapid advances in glycoprotein chemistry would seem to warrant an analysis of the subject. Consequently, more exact data are needed concerning the occurrence, genesis, and physiology of the native chondroitin sulphate. The complexity of the problems justifies a short review of the present conceptions of cartilage physiology with reference to chondroitin sulphate. The author is fully aware of the difficulties involved in presenting any interpretations of final importance.

QUALITIES OF CHONDROITIN SULPHATE

The chemical composition of the degraded chondroitin sulphate, or chondroitin-sulphuric acid, is well known [22, 23, 32, 33, 37, 44, 48]. The native substance presents a long-chain structure [4, 7, 30, 32, 33], has a very high molecular weight, and is slightly viscous in solution. The fibrous precipitates show little coherence. Chondroitin-sulphuric acid has a strongly acid reaction, due to both ester sulphate and carboxyl groups, which is of physiological interest. In cartilage, the substance is probably combined with protein by salt, or by other linkage [30]. On extraction with dilute alkali, the molecule is easily depolymerized [4], and consequently the relative viscosity is also influenced by slight variations in the pH of the solvent. Thus, the molecule presents a *sensitivity* which may be of fundamental importance in the interpretation of cartilage physiology.

METHODS OF DETERMINATION

The old *macrochemical* method involves extraction by weak alkali, and subsequent analysis of the degraded molecule [22, 23]. By the use of saline solutions for the extraction, more native preparations have recently been obtained [4, 7, 30], but the yield has usually been very low.

The metachromatic staining reaction, according to Lison, forms a qualitative test for the demonstration of ester sulphates of high molecular weight. Consequently, this staining reaction may be used for the *histochemical* assay of chondroitin sulphate, if no other ester sulphates are present in the same section. As far as we know, this happens to be the case in cartilage. If certain technical requirements are fulfilled when the sections are prepared (namely, uniform thickness and a standard staining technique), this method will also permit an approximate quantitative estimation of the content of ester sulphate [49, 50]. The metachromatic staining reaction has a very high degree of sensitivity [20]; and, with regard to the content of chondroitin sulphate in cartilage, it has given results which correspond very well with those obtained by the macrochemical method [17].

Unfortunately, no better methods are as yet available. It seems advisable to use both methods, since each has advantages of its own. The metachromatic reaction is, however, of prime importance for the exact localization of the ester sulphates under discussion.

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CHONDROITIN SULPHATE IN CARTILAGE

Origin

Most authors assume that the chondrocytes elaborate this substance[10], but direct evidence is still lacking. Hansen has scrutinized different theories, without settling the question. Clark and Clark were unable to decide whether the hyaline matrix was produced by the chondrocytes or by some alteration of the intercellular medium. The observation that the chondrocytes are surrounded by a large amount of chondroitin sulphate has thus far served as indirect proof of its elaboration by the chondrocytes; but, remarkably enough, no precursor has been demonstrated in the cell cytoplasm by histochemical or other methods. Thus, nothing is known of the ester-sulphate metabolism in cartilage. Additional data are needed badly, and will probably be supplied by using labeled sulphur. Some factors influencing the production of chondroitin sulphate will be mentioned in this paper.

Distribution

A small amount of ester sulphate can be demonstrated in the precartilaginous mesenchyme[19, 28]. In the embryo, the cartilage anlage becomes enveloped by a connective-tissue sheath, the perichondrium, which is supposed to serve as a "protecting" membrane. Inside this closed structure, growth and differentiation of cartilage proceed, and the specific matrix is developed. During the embryonic development, there is a low ratio between matrix and cells; this ratio increases during infancy, until the typical ratio in each type of cartilage is reached. No analytical data are available concerning the amount of chondroitin sulphate in embryonic cartilage but, judging from the metachromatic reaction, the amount seems to be fairly high. It seems by no means impossible that the local percentage concentration of chondroitin sulphate in the intercellular medium could be nearly as high as in adult cartilage.

Chemical analyses have shown that each type of cartilage has a certain normal amount of chondroitin sulphate (Table I). Maximum amounts have been reported in the adult period of life[15, 36]. Additional details regarding articular cartilage are included in reviews by Hansen, Benninghoff, and Hirsch.

The validity of the percentages of chondroitin sulphate given in Table I is limited, because of several factors. The figures give no information as to the regional variations in content of ester sulphate, nor as to the local concentration of chondroitin sulphate in the intercellular substance. From a biological point of view, such data would be extremely valuable; and they may be obtained by using a technique for histochemical determination. These questions have, to some extent, been studied by earlier authors, but sufficient data are still lacking[42].

To illustrate the regional variations in ester-sulphate content, it may be mentioned that the surface zones of articular cartilage generally contain a smaller amount of metachromatic material than the perpendicular zone[3, 14, 17, 42]; a proper explanation for this observation is still lacking. On the other hand, many investigators have stated that the local concentration of chondroitin sulphate is maximum around the chondrocytes, and that the amount decreases farther off into the intercellular substance. Theories have been advanced for the interpretation of this fact, but final proof is lacking.

Chemical [15, 36] and histochemical investigations [42] would suggest a constant depletion of chondroitin sulphate with aging. This fact must be correlated with a number of different factors and simultaneous changes affecting cartilage during this period of life. From infancy to old age, a continuous decrease in the number of cells is found in articular cartilage[40]. At the same time, the content of calcium increases[15]. In addition, a continuous process of cell degeneration proceeds, accompanied by many changes,—such as calcification, pigmentation, amianthoid degeneration, and fibrous metaplasia of cartilage. The

TABLE I

THE PERCENTAGE OF CHONDROITIN SULPHATE IN DIFFERENT TYPES OF CARTILAGE

Species	Age or Body Weight	Origin	Type of Cartilage	Amount of Chondroitin Sulphate in Dried Cartilage (*Per Cent.*)	Bibliographic Reference
Man	Young	Nasal septum	Hyaline	39–40	Miyazaki
Man	Middle aged	Nasal septum	Hyaline	26–33	Miyazaki
Pig		Nasal septum	Hyaline	41	Winter
Horse, ox, and pig		Nasal septum	Hyaline	37–38	Miyazaki
Horse and ox		Trachea	Hyaline	36–37	Miyazaki
Pig		Cricoid cartilage	Hyaline	38	Miyazaki
Man	35 years	Costal cartilage	Hyaline	11.4	Hass
Man	47 years	Costal cartilage	Hyaline	8.5	Hass
Man	60 years	Costal cartilage	Hyaline	6.9	Hass
Man	66 years	Costal cartilage	Hyaline	4.8	Hass
Rabbit	500–700 grams	Costal cartilage	Hyaline	37–38	Miyazaki
Rabbit	1,000–1,200 grams	Costal cartilage	Hyaline	29–31	Miyazaki
Rabbit	About 2,000 grams	Costal cartilage	Hyaline	23–24	Miyazaki
Man	40–48 years	Patella	Hyaline	19–25	Hirsch
Ox and rabbit		Knee joint	Fibrocartilage	15	Miyazaki
Horse, ox, and pig		External ear	Elastic	27–28	Miyazaki

possible effects of loss of mechanical function should not be overlooked, this loss being able to affect both the metabolism and the degree of differentiation of cartilage. Evidently, there is as yet no simple interpretation to explain the gradual loss of chondroitin sulphate. Hass has suggested that the production of chondroitin sulphate by the chondrocytes diminishes with aging, but the explanation may be much more complicated.

WATER CONTENT OF CARTILAGE

The intercellular matrix of normal cartilage constitutes a gel, containing about 70 per cent. water. The water content is dependent upon the actual chemical constitution of the chondroitin sulphate, and of the proteins and other electrolytes present. Changes in the composition and relative amounts of these substances result in changes of the water content. Thus, the content of water is a secondary phenomenon, and may be regarded as an indicator of alterations in the composition of the components of the gel. Therefore, the isolated study of the water content is of minor interest and is, moreover, very difficult to explain in detail.

NUTRITION OF CARTILAGE

It is generally agreed that cartilage, being largely devoid of vessels, gets the nutritive fluid by diffusion from the blood vessels of the perichondrium. This means that the fluid must pass through the interstitial substance to reach the chondrocytes[13, 28]. It is well known that injected dyestuffs are absorbed quickly by the cartilaginous matrix[28, 42]. With articular cartilage, we face more complicated conditions,—namely, nutritive exchange by percolation from the underlying bone, by diffusion through the synovial fluid, or perhaps in both ways[13]. As yet, we have no definite knowledge of the governing factors of this suggested diffusion mechanism. The physicochemical side of this mechanism is particularly obscure.

Thus, we do not know how the diffusion process is effected; we know only that it works in healthy cartilage. It may be postulated that such nutritional conditions render cartilage susceptible to alterations of the perichondrial connective tissue and of the syno-

vial membrane and fluid, respectively. Accordingly, knowledge is scant as to the morphological changes in cartilage, due to derangement of nutrition. In this respect, Maximow and Bloom suggest that articular cartilage will become dedifferentiated when mechanical function has deteriorated, and this might also imply a disappearance of chondroitin sulphate. The so-called "dedifferentiation" of cartilage cultured *in vitro* is discussed in a later section.

METABOLISM OF CARTILAGE

The concept has been adopted that cartilage metabolism decreases gradually with old age, largely because of the gradual decrease in the number of cells. The rate of glycolysis was found to be proportional to the number of cells, but oxygen consumption decreased more rapidly, indicating a progressive cell degeneration with aging[40]. The glycolytic and oxidoreduction enzyme systems of cartilage were reviewed by Lutwak-Mann. Very little is known concerning the metabolism of fat and proteins in cartilage.

We are forced to assume a continuous exchange of chondroitin sulphate in normal cartilage, comprising some consumption and resupply, but the details have not been established. In all probability, the turnover of chondroitin sulphate will also become a part of the future research on sulphur and sulphate metabolism. Some changes taking place in the metabolism of cartilage have, however, been described in immature guinea pigs, which were subjected to undernourishment, thyroidectomy, and the administration of pituitary extracts[45, 46, 47]; but, unfortunately, the technique for the demonstration of chondroitin sulphate was imperfect, so that no conclusive statements could be made.

Rickets

In rickets, the hypertrophic epiphyseal cartilage cells present the usual staining reactions. Thus, there is probably no decrease in chondroitin-sulphate content, a suggestion supported by the analysis of Miyazaki. Pierce reported the same hydrogen-ion concentration in both healthy and rachitic epiphyseal cartilage. On the contrary, the simultaneous degeneration of matured cartilage cells on the diaphyseal side is known to be associated with a rapid disappearance of chondroitin sulphate[43], a process which corresponds to normal endochondral ossification.

Scurvy

It is generally assumed that the formation of the cartilaginous matrix is impaired in vitamin-C deficiency[21]. Using a defective metachromatic staining technique, Meyer[29] recently asserted that the production of chondroitin sulphate was prevented in scorbutic cartilage. Conclusive results concerning this are lacking, as is also a comparison with the content of alkaline phosphatase in scorbutic cartilage[6, 12].

Regarding the metabolism and possible turnover of chondroitin sulphate in articular cartilage, we should consider the possible role of the so-called "hyaluronic acid" and the corresponding enzyme system "hyaluronidase". The synovial fluid contains hyaluronic acid[34], which has a composition related to that of chondroitin sulphate[8]. Hyaluronic acid is hydrolyzed by hyaluronidase and, furthermore, this enzyme group also hydrolyzes both the isolated, partly depolymerized chondroitin sulphate[31, 38] and the native substance, according to Hirsch. Hyaluronidase has been obtained from many bacteria and, in large quantities, from testes[26, 34], but has not yet been demonstrated in synovial fluid. The results outlined in this paper may contribute to the future solution of many problems, particularly with regard to the genesis and metabolism of chondroitin sulphate in articular cartilage, under both normal and pathological conditions. In all probability, the enzyme will be demonstrated in synovial fluid; and this might serve as an explanation for the low content of chondroitin sulphate in the superficial part of articular cartilage. On the other hand, an increased content of hyaluronidase of bacterial origin would explain

the rapid destruction of chondroitin sulphate, and possibly also that of cartilage, which occurs in some types of arthritis.

REGENERATION OF CARTILAGE

In adult cartilage, mitosis probably never occurs. The new formation is brought about by metaplasia of loose connective tissue, according to Maximow and Bloom. The slow development of cartilage cells from perichondrial cells and fibroblasts was studied by Clark and Clark, using the transparent chamber technique. From the standpoint of functional pathology, the metaplastic formation of new cartilage is an extremely slow process, extending over several months.

CULTIVATION OF CARTILAGE *IN VITRO*

Cultivation of small fragments of cartilage usually results in a subsequent dedifferentiation to a fibroblast-like cell type, and a rapid loss of chondroitin sulphate. On the contrary, cultivation of the whole cartilaginous anlage with the enveloping perichondrium permits a slow growth of cartilage containing chondroitin sulphate [5, 11, 16, 27, 35, 41]. In this way, the differentiation and growth of cartilage, the new formation of cartilage from mesenchyme and perichondrium, and to some extent the intramembranous and endochondral ossification have been studied *in vitro*.

Roulet cultivated simultaneously fragments of epiphyseal cartilage which were devoid of perichondrium, and rapidly growing fibroblasts; and he observed that, when they came into contact with each other, the cartilage matrix lost its metachromatic and basophilic staining reactions, and became acidophilic. The loss of ester sulphate was accompanied by degeneration of the chondrocytes, and after some time the fibroblasts digested the cartilage plate. A digestion process took place, apparently characterized by an early disintegration of the chondroitin sulphate. Roulet assumed, in conformity with Weidenreich, that some freely diffusible enzyme, liberated by the fibroblasts, was responsible for this. This experiment is of considerable interest, and would appear to be useful in explaining some processes in functional pathology. However, serious objections can be raised to this interpretation.

The observations of Roulet lose in value when the slightly alkaline reaction of the culture media and the sensitivity of the chondroitin-sulphate molecule [4] are considered. This applies also to most of the other experiments in cultivation of cartilage fragments which are devoid of perichondrium. Apparently, the usual culture media are unsuitable for the specialized nutritional requirements of cartilage. Nature itself sometimes starts cartilage cultures with more success,—namely, in the shape of intra-articular loose bodies, which show normal cartilage with a normal content of chondroitin sulphate. Obviously, the nutritional conditions in the synovial fluid are sufficient for both growth and maintenance of cartilage for many years [13].

THE FUNCTION OF CHONDROITIN SULPHATE

The aspects of cartilage physiology, mentioned previously, accentuate the necessity for analyzing the different qualities of chondroitin sulphate, in order to reach an opinion as to the functional significance of this substance in healthy cartilage. Obviously, the healthy state of hyaline cartilage must in some way be associated with a high content of chondroitin sulphate in its intercellular matrix. It is tempting to speculate that very specialized tissues (such as cartilage, the cornea, and the connective tissue of the umbilical cord), containing large amounts of glycoproteins, might have some qualities in common, which could give a hint as to the function of the glycoproteins.

Acidity

The significance of the strongly acid reaction of chondroitin-sulphuric acid is obscure.

The suggestion may be advanced that the acid reaction favors some enzyme systems, while inactivating others. In another paper on this subject, to be published later, this question will be treated with regard to the action of alkaline phosphatase. However, the elucidation of this important question is hampered by the present defective knowledge of the native state of chondroitin-sulphuric acid and its protein linkages.

Molecular Structure

A recent report by Barcroft and his associates, on the diffusion rate of certain dyes in Wharton's jelly, is of especial interest. Their results favor the suggestion that this tissue might serve as a non-vascular conducting path for nutritional fluids and substances. Without presenting any experimental proof, Bacsich and Riddell have advanced the idea that this non-vascular pathway was effected by the ester sulphates present in Wharton's jelly. The corresponding suggestions should also be applicable to the cornea and cartilage. However that may be, it seems probable that the molecular structure in some way might favor diffusion; but conclusive evidence is needed.

Mechanical Function

According to Hirsch, chondroitin sulphate is partly responsible for the maintenance of cartilage elasticity. Patellar cartilage with a reduced content of this substance always exhibits impaired elasticity, "particularly a deterioration in its capacity to withstand loading". Hirsch, however, did not go further into the physicochemical interpretations of this observation.

Further suggestions might be advanced, but they would seem to be unjustified, because of the present very defective knowledge of the possible function of chondroitin sulphate.

DISCUSSION

This review is intended to emphasize that our views on cartilage have until now been largely morphological. Evidently, we have neglected the biological significance of chondroitin sulphate. By focusing our attention on this substance, and with the aid of the recent advances in glycoprotein chemistry, we should arrive at another and perhaps more biological opinion. We have good reason to assume that *chondroitin sulphate occupies the central position in cartilage biology*, and probably plays a very important role in the metabolism and function of cartilage. Most of our current problems concerning cartilage deal, or will in the near future be dealing, with the occurrence, distribution, and function of chondroitin sulphate. When we consider the physiopathology of cartilage, it seems still more urgent to get new information on the changes influencing this substance and on the physiological effect of such changes. It would be fruitful in a future approach to concentrate more interest on the role played by chondroitin sulphate.

NOTE: Two other articles on this subject, written by the same author, have been received and will appear in subsequent issues of *The Journal*.

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AN OPERATION FOR OLD UNREDUCED BENNETT'S FRACTURE

BY JOHN R. VASKO, M.D., OAKLAND, CALIFORNIA

The old unreduced Bennett's fracture is frequently a very disabling condition, because of the deformity present and the resulting traumatic arthritis. It is characterized by weakness of the grip, pain upon motion, and a prominent carpometacarpal joint, caused by swelling and the dorsal metacarpal dislocation. In the author's experience, all the unreduced Bennett's fractures produced symptoms, the severity of which depended upon the patient's occupation and mental state. Since the unreduced fracture-dislocation is accompanied by traumatic arthritis, the symptoms are unlikely to improve greatly until the faulty mechanics have been corrected by a surgical reconstruction. The perfect restoration must be a physiological one, and must return the finger to normal anatomically. A successful technique, which meets these requirements and which has resulted in strong and painless hands, is presented.

ANATOMY [4]

The base of the first metacarpal articulates with the greater multangular and is saddle-shaped, fitting over the multangular. The metacarpal is held in place chiefly by the capsular ligament, which is stronger in certain places because of thickened portions or bands. Three of these bands are located on the volar surface, connecting the greater multangular and the first metacarpal, the largest of them being inserted into the palmar portion of the saddle of the metacarpal (Fig. 1). It is this ligament, whose chief function is to prevent a radial dislocation of the metacarpal, which becomes inactive in a Bennett's fracture, because the fracture occurs distally to the ligament's insertion into the process (Fig. 2).

The only muscles which are inserted into the base of the first metacarpal, and which therefore might influence the dislocation of the base in a Bennett's fracture, are three: the flexor pollicis brevis, the abductor pollicis longus, and the opponens pollicis. Only the proximal fibers of the flexor pollicis brevis are inserted near the base; the larger portion of the muscle has its insertion distally into the first metacarpal. Hence its effect upon the base during a dislocation would be minimum, as its chief actions are to flex, abduct, and rotate inward the metacarpal of the thumb; flex the first phalanx; and extend the second phalanx.

The opponens pollicis has its insertion along the whole lateral border of the volar surface of the shaft and head of the first metacarpal; and its main action is to flex, abduct, and rotate inward the first metacarpal.

The abductor pollicis longus is inserted into the radial side of the base of the first metacarpal. Its actions are to carry the first metacarpal radialward and forward, and at the height of its contraction it flexes the hand at the wrist. It is also a weak supinator of the forearm.

It is thus seen that none of the only three muscles which are inserted into the base of the first metacarpal are very effective in preventing a radial dislocation of the base; and one of them, the abductor pollicis longus, tends to assist such a dislocation. The only effective control of such a dislocation, therefore, is the radially placed thickened band of the ligamentous capsule; when this has been made inactive by fracture, dislocation occurs, being assisted by the abductor pollicis longus.

PATHOLOGY

In a fresh Bennett's fracture [1], the palmar portion of the base of the first metacarpal is broken off; an outward dislocation of the base occurs; and there is some degree of tearing of the carpometacarpal ligamentous capsule (Fig. 2). In the old case, the two bone frag-

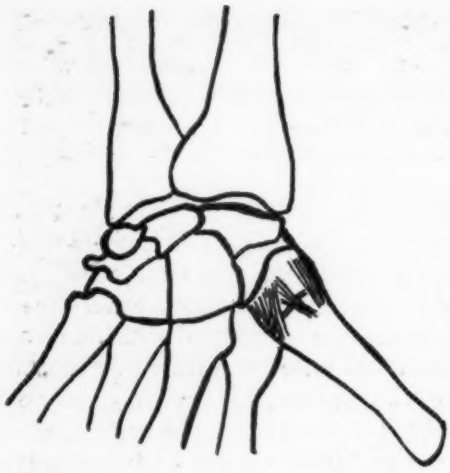

FIG. 1

FIG. 2

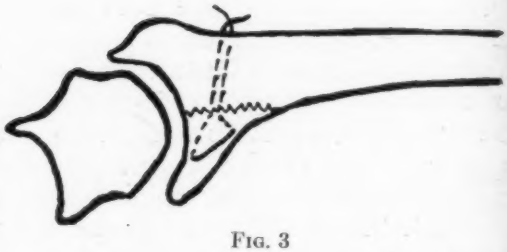

FIG. 3

Fig. 1: Diagram illustrating the capsular ligament of the first carpometacarpal joint on the volar aspect.
Fig. 2: Diagram illustrating a Bennett's fracture-dislocation.
Fig. 3: Diagram illustrating the method of maintaining reduction of the fracture with a mattress suture.

ments either remain separated, or are malunited in such a way that the mortise effect of the base of the first metacarpal is lost. The smaller fragment usually becomes united distally to the normal position; thus the palmar portion of the concavity, fitting over the greater multangular, and consequently the buttress effect, are lost. Malunion had occurred in all of the last three patients whom the author operated upon; and in one other case nonunion of the smaller fragment was present. Traumatic arthritis of the carpometacarpal joint is also present in varying degree.

SYMPTOMS

The symptoms in all cases were similar. They consisted of weakness of grip, pain with use of the thumb, swelling of the carpometacarpal joint, and a dorsal prominence of the proximal end of the first metacarpal. In all patients these complaints had existed since the time of the original injury, and they were proportional to the amount of use of the hand. The severity of the symptoms also varied; it was noticed that patients with nervous temperaments complained more, as did those whose occupations necessitated greater use of the hand. All of the patients were willing to submit to an operation in order to improve the result.

TREATMENT

To repair the unreduced fracture physiologically, it is necessary to restore the ulnar portion of the saddle of the first metacarpal to its normal position, and thus restore the concavity. Following union, the dislocation cannot recur, as the previously inactive capsule begins to function. Bunnell recognized the necessity for such a repair, and was successful in using stainless-steel pins to hold the fragments together after open reduction. In the operation to be described, a mattress suture is utilized to hold the fragments together after they have been reduced.

OPERATION

After a tourniquet has been applied, a linear incision, one and one-half inches long, is made over the dorsum of the base of the first metacarpal and to the volar side of the extensor pollicis longus tendon. The incision is carried down to the bone, and the opponens

FIG. 4-A

FIG. 4-B

Fig. 4-A: Preoperative roentgenogram of unreduced Bennett's fracture, illustrating the dislocation and malunion.

Fig. 4-B: Roentgenogram taken after operation shows reduction of the fracture-dislocation and restoration of the metacarpal mortise.

pollicis and flexor pollicis brevis are then stripped off, so that the carpometacarpal joint is exposed on the palmar side. Care must now be exercised in exposing the fracture site, as that part of the capsule attached to the smaller fragment must not be cut. A small linear incision is made into the capsule over the fracture site, where it is usually found that the smaller fragment has united distally to the normal position. Separation of the malunited bone is made with a small osteotome, and two small drill holes are than placed in the smaller fragment. This must be done with care, so as to avoid fragmentation. A drill hole is then made in the base of the metacarpal, from the dorsal to the volar surface. By abduction of the thumb and the application of pressure on the base to reduce the dislocation, the mortise is restored. Reduction of the fracture is maintained with a mattress suture of cotton, No. 24. This runs through the drill holes and is tied on the dorsum, after including the periosteum on each side, at the same time abducting the thumb (Fig. 3). This abduction and inward pressure of the base of the metacarpal must be maintained during the rest of the operation and the cast application, because there is a tendency for the dislocation to recur, owing to the contracted capsule on the radial side of the joint.

After closure, a gauntlet type of cast is applied, with the thumb included down to the interphalangeal joint. The cast is left on for four weeks, after which gradual active motion is begun.

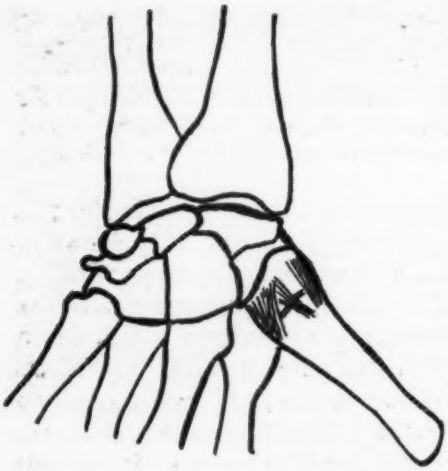

FIG. 1

FIG. 2

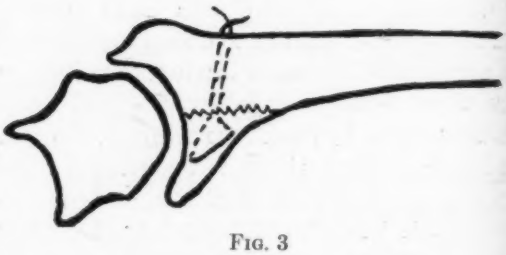

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FIG. 4-A

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After closure, a gauntlet type of cast is applied, with the thumb included down to the interphalangeal joint. The cast is left on for four weeks, after which gradual active motion is begun.

RESULTS

Three consecutive cases were treated by the technique described, and the results were excellent in all. There was no pain, and the strength of the grip approached normal. The final roentgenograms showed that the smaller fragment was in a more normal position and that the mortise had been restored. Two of the three patients were seen periodically in the Out-Patient Clinic for several months and the results remained good, the patients being free of symptoms and able to perform their full duties. The third patient was seen for some weeks after operation, and the result was good when he was last seen. The roentgenograms of a typical case, before and after operative repair, are shown in Figures 4-A and 4-B.

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PAINFUL INTERDIGITAL CLAVUS (SOFT CORN)

Treatment by Skin-Plastic Operation

BY EDWARD J. HABOUSH, M.D., AND ROBERT V. MARTIN, M.D., NEW YORK, N. Y.

Painful interdigital clavus and its etiology are well known. The conventional operation for the relief of this condition usually consists of a partial resection of the fourth metatarsophalangeal joint. This procedure appears to be a rather radical method of treatment for such a minor lesion.

Basically, the principle of the conventional operation is the removal of the normal underlying bone impinging upon the skin. The same effect can be attained more logically, however, by removing the overlying pathological skin of the affected toe and, by a simple

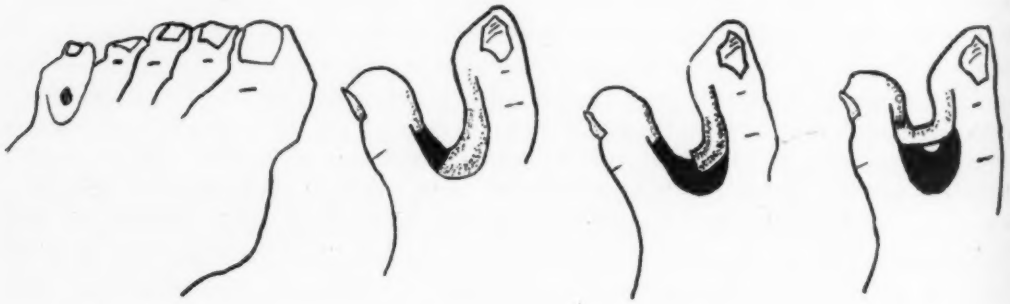

Fig. 1 Fig. 2 Fig. 3 Fig. 4

Fig. 1: Relation of soft corn to foot.
Fig. 2: Fourth and fifth toes spread apart, showing interdigital area. The soft corn has been excised; bare area is in black. Lines of incision shown for dorsum only.
Fig. 3: Medial skin flap being mobilized.
Fig. 4: Flap has been advanced and sutured. Defect left in black.

FIG. 5 FIG. 6 FIG. 7 FIG. 8

Figs. 5 and 6: Suture of skin edges to each other and to flap. Note that web has been advanced.

Fig. 7: Plantar aspect; shows remaining defect.

Fig. 8: Method of raising flap.

Fig. 9: Flap has been raised.

Fig. 10: Flap has been mobilized and sutured.

FIG. 9 FIG. 10

skin flap, advancing the web distal to the underlying impinging normal bone. This operation has been performed on twenty toes, although the total number of patients was seventeen, as three cases were bilateral. All results were gratifying. In one case, necrosis developed in the flap; but the area became epithelialized and the web remained advanced.

The operation consists of (a) excising the painful interdigital clavus; (b) turning up a skin flap from the lateral aspect of the fourth toe; and (c) forming a sliding skin flap on the plantar aspect of the foot at the base of the fourth toe.

OPERATIVE PROCEDURE

Following excision of the soft corn on the fifth toe, a skin flap is turned up on the lateral aspect of the fourth toe, based distally, and is sutured to the distal edge of the skin from which the clavus has been removed (Figs. 1, 2, 3, and 4). Three interrupted silk sutures are sufficient for this step of the operation. The free dorsal edges of the wound on the fourth and fifth toes are then sutured together and to the free dorsal edge of the skin flap, forming a Y closure (Figs. 5 and 6). On the sole of the foot, from the base of the fifth toe in the lateral re-entrant angle of the still open plantar wound, an incision, three-quarters of an inch long, extending proximally, is made. The skin flap is then undermined and mobilized, thus simply effecting a closure of the plantar defect (Figs. 7, 8, 9, and 10).

The sutures are usually removed at the end of ten days. Frequent dressings are advised, beginning as early as the second day after operation. This keeps the wound dry and prevents maceration of the tissues, so common to the interdigital areas. With the operation described, convalescence is shortened. After removal of the sutures, the patient is able to walk without pain. After this operation, there is no possible danger of recurrence. In the experience of the authors, it offers distinct advantages over the conventional operation.

OBSERVATIONS ON OBSCURE MECHANISMS OF NERVE-ROOT COMPRESSION WITH A DIAGNOSTIC TAP TEST

Report of Two Cases

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In the study of the surgical relief of sciatic pain associated with backache, the authors have recently encountered an unusual mechanism of nerve-root compression, and have discovered a test of foraminal-root pressure, for use during an operation.

The unusual mechanism found was the compression of a nerve root against the superior pedicle and articular process in the foramen, by the disc bulging out below or distal to the root. A contraction of the gluteal and thigh muscles upon tapping the overlying facet proved to be the result of compression of the nerve root in the foramen.

Case 1. J. F. C., a machinist, aged forty-two, was admitted on December 28, 1945, complaining of severe pain in the lower part of the back and in the right buttock, thigh, and leg. He stated that he had injured himself five days before, while pushing a tool machine. Examination showed that he had an acute low-back affection with a loss of the ankle jerk on the right side.

At operation the fifth, fourth, and third intervertebral discs were explored. The only pathological change noted was that in the fourth disc, underneath the fifth root, there seemed to be an area of degeneration. A window was cut in the fourth disc at this point, and a piece of somewhat hard and degenerated material was removed with a pituitary forceps. Preparations were then made to perform a low-back chip fusion, and a rasp was hammered into the articulation joining the fourth and fifth vertebrae on the right side. A muscular contraction of the right buttock and posterior thigh muscles was observed. A complete foraminotomy [2] was then performed between the fourth and fifth vertebrae, with a wide opening of the intervertebral foramen. The response to tapping disappeared completely. It was observed that the disc bulged out into the foramen where it curved around to the lateral border of the spinal column. The protruding disc was shaved off with a scalpel, and the fusion was carried out between the fourth and fifth lumbar vertebrae.

This patient was discharged from the Hospital on the fifteenth postoperative day. He returned to work in April, three months following operation, and was last examined on May 3, 1946.

This case presented interesting features. The bulge of the fourth lumbar disc at its lateral border was not discovered until a complete foraminotomy had been performed, and only after this procedure did the contractions of the gluteal and thigh muscles, in response to tapping on the articulation, cease.

The authors are convinced that they would not have relieved the compressing mechanism which was producing the sciatic pain unless the observation of the muscle reaction to the tap on the articular process had given the clue to the presence of pathological changes in the underlying foramen.

Case 2. G. D., an ex-serviceman, aged twenty-one, who was admitted to the Hospital March 11, 1946, complained of severe pain in the lower part of the back with radiation of the pain down the posterior aspect of the right lower extremity. This discomfort had started insidiously about a year and a half previous to his admission, while he was a member of the Armed Forces. Physical examination showed limitation of back motion in all directions, positive straight-leg raising tests on both sides, and a diminished ankle jerk on the right side.

The patient was operated upon March 20, 1946. The fourth and fifth discs were explored, and, as is commonly found in young individuals, both discs were bulging. The fifth disc, however, had a very prominent posterior bulge. On the right side, a window was cut in the annulus beneath the first sacral root, and some disc material was removed, which, as is usually found in the young, was not degenerated. Preparations for a lumbosacral fusion were then started, and a rasp was driven into the lumbosacral articulation on the right side. There was a violent contraction of the left or opposite buttock and thigh muscles. The fifth disc on the left side was then explored. A window was cut in it, and disc material was removed from beneath the first sacral nerve root, but tapping still caused the muscles to contract. A complete laminectomy was performed on that side, and the foramen was visualized, but still the contraction on tapping persisted. It then became

apparent that the disc had bulged out into the foramen and had pressed the fifth root up against the pedicle and articular process of the fifth vertebra. When this pedicle had been partially removed, the response to tapping ceased. After the nerve roots had been covered with fat, a lumbosacral chip fusion was performed.

The patient remained in the Hospital about thirty-eight days and was last seen on July 10, 1946. His original complaints had entirely disappeared, and he was told to return to light work.

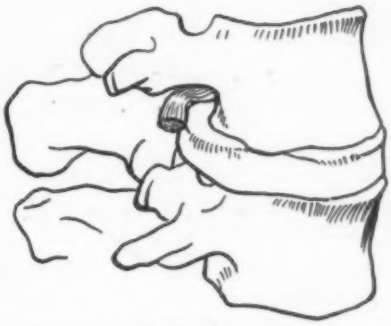

FIG. 1

Shows the mechanism of compression as found in Case 2.

In reviewing this case, the authors felt that this was the second case in which tapping on the articular processes revealed the site of pathological changes. It also showed a new mechanism of root compression,—namely, a compression of the nerve root in the foramen by a bulging disc which pressed the nerve root against the pedicle and articular process of the superior vertebra (in this case the fifth lumbar vertebra).

Many times, in performing what they consider to be a complete foraminotomy, the authors have removed a portion of the inferior pedicle. They feel that they have located, in this second case, a mechanism of foraminal-root pressure, formerly overlooked. Exploration with a probe or with a catheter and stylet would not reveal this type of compression in the foramen, because, in this case, there was plenty of room distal to the root in the foramen. It would seem that actual visualization of the nerve root and the disc in the foramen is necessary before one can consider a segment to be explored thoroughly.

These two cases illustrate the value of tapping on the articular processes to determine whether or not there is a compression of the roots in the foramina. Our present routine in operating upon the low-back region is, after the exposure of the spinous processes and laminae, to test the mobility of the segments exposed, and then to carry out the tapping procedure.

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XANTHOMA OF THE ACHILLES TENDON *

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Xanthomatous tumors of the tendon sheaths are not uncommon, but only a few cases have been reported in the literature in which the tumor involved the Achilles tendon. Two cases of bilateral xanthomata of the Achilles tendon are recorded here, in both of which the tumors were among the largest of this type so far reported. One patient had multiple xanthomatous lesions on the hands and feet, in addition to those of the Achilles tendon. The second patient had isolated tumors of both heel cords.

CASE REPORTS

CASE 1. A white woman, forty-five years of age, was admitted to the Illinois Research Hospital† in April 1938, complaining of pain in the fingers and painful swelling of both heel cords. Ten years previously her attention had first been called to a small growth in the lower part of each Achilles tendon. These masses gradually enlarged and became painful. About three years before admission, a small painful tumor appeared on the left big toe; and subsequently several small tumor masses gradually appeared on the fingers of both hands. The past history and the family history were non-contributory.

Physical examination showed the patient to be a moderately obese, middle-aged white woman. Several small yellow plaques were present on both lower eyelids. On the extensor surfaces of the fingers of both hands were multiple small, hard, yellowish-brown tumors, which varied in size from 0.5 by 1 centimeter to 1.5 by 3 centimeters. Somewhat larger tumors were present on the extensor surfaces of both big toes and over both patellar tendons. Both Achilles tendons were enlarged about three to four times the normal size. The tendons felt hard and nodular, and were somewhat tender. The motion in the ankle joints was unrestricted.

The blood count and urine were normal. The blood-chemistry findings were as follows: sugar 118 milligrams, cholesterol 620 milligrams, and uric acid 4.5 milligrams per 100 cubic centimeters. The Wassermann reaction of the blood was negative.

On April 20, 1938, both Achilles tendons were explored. Each tendon was found to be infiltrated by a yellowish, hard, nodular mass, extending from the musculotendinous junction to the calcaneus. The greater part of this mass was resected in both legs. After the operation, the wounds healed *per primam*. The pain in the fingers was relieved by a few treatments with deep roentgen rays.

Microscopic examination of the tumor tissue disclosed collections of polyhedral cells, with abundant pale vesicular foamy cytoplasm and small irregularly shaped nuclei. The stroma consisted of oval stroma cells, with slightly granular cytoplasm and oval nuclei. Numerous vesicular lipoid-filled spaces were scattered throughout the tissues. The blood vessels were abundant. A few giant cells were found near areas of hemorrhage. The tumor was surrounded by a well-defined fibrous capsule, extending from which numerous fibrous septa subdivided the tumor into lobules. The microscopic diagnosis was xanthomata.

During the next four years, ten tumors of varying sizes were removed from the fingers, toes, and elbows. The largest of these, taken from the right triceps tendon, was the size of a hen's egg. The tumors were excised because they were causing pain. The microscopic picture of these lesions was identical with that just described. The blood cholesterol varied from 384 to 800 milligrams per 100 cubic centimeters.

Late in 1942, the patient again complained of pain and enlargement of both heel cords. In February 1943, the Achilles tendons were explored. Again the tendons were found to be diffusely infiltrated by a yellowish nodular mass, extremely fibrotic for the most part, except for a few areas of caseous softening. The greater part of the tendon was resected, leaving only a thin strip of tendon. The wounds broke down repeatedly and healed very slowly. The plantar-flexion power, weak at first, gradually increased as the resected tendons were replaced by thick scar tissue, and as the posterior tibial muscles and peronaei became increasingly stronger plantar flexors.

When the patient was last seen, in January 1945, she had no pain in her legs. The wounds were healed. A thick fibrous cord was palpable at the site of each Achilles tendon. There was a mild bilateral pes cavus deformity. The ankles could be dorsiflexed to 100 degrees. Plantar flexion was strong enough to enable her to stand on her tiptoes. Her gait was normal.

CASE 2. A white woman, thirty-seven years old, was admitted to the Cook County Hospital on December 6, 1943, because of progressive enlargement of both heel cords. Nine years before admission, she had first noticed a small, hard swelling over the lower part of each Achilles tendon. These masses gradually increased in size, until they extended as high as the middle third of the leg. The patient did not complain of pain and

* Read before the Chicago Orthopaedic Society, February 8, 1946.

† Service of Fred W. Hark, M.D.

had no limp. She sought medical advice merely for cosmetic reasons. There was no history of injury to either leg. Her past history was essentially negative.

Physical examination was negative, except for the very unusual appearance of her legs. On the posterior aspect of each leg was a large bulging sausage-shaped mass, extending from the lower calf region to the heel (Fig. 1-A). The masses were hard and nodular, but not tender to palpation. On the right leg the mass measured 8 centimeters in width and 23 centimeters in length, and on the left side it measured 7 by 20 centimeters. There was no restriction of plantar flexion or dorsiflexion in the ankle joint. No other tumor masses or nodules were found. A roentgenogram of the leg showed no bone changes. A diagnosis of bilateral xanthoma of the Achilles tendon was made.

The blood count and urine were normal. The blood cholesterol was 245 milligrams and the cholesterol esters 142 milligrams per 100 cubic centimeters.

On December 9, 1943, both Achilles tendons were explored. Each tendon was about five or six times its normal size. The entire tendinous structure was infiltrated by sclerotic, bright yellow fibrous tissue, and was studded with nodules of varying sizes and shapes (Fig. 1-B). The nodules presented a variety of shades including golden yellow, ocher yellow, and yellowish brown. No normal tendon tissue was present. On the surface of the lower part of the tendon were two or three areas of softening, with a caseous consistency. The greater part of the tendon was cut away in the frontal plane, so that the remainder approached the normal size. Wound healing was delayed until four weeks after the operation. The patient gradually began weight-bearing, and six weeks after the operation she was sent home.

On subsequent follow-up visits to the Out-Patient Clinic, the patient complained only of mild ache and pain in the calves. There was some tenderness and induration along the lower part of the Achilles tendons, and slight shortening of the heel cords. When last seen, in June 1945, the patient had no pain and no limp. There was only slight residual equinus deformity. She was able to stand on her toes. The Achilles tendons were slightly enlarged, but they apparently had not increased in size since they were resected.

The histological examination of the tumors revealed a lobulated structure, containing large deposits of cholesterol. In some areas, the cholesterol deposits were surrounded by multinucleated giant cells. The lobules were demarcated by a proliferation of a collagenous type of connective tissue, which was more or less acellular except for the regions adjacent to the blood vessels. In these areas, the collagenous tissue was more cellular; and imbedded among the fibers were small nests of foam cells. In the periphery of the nodule, the tissue was more cellular and contained numerous large nests of foam cells.

HISTORICAL REVIEW

The first report of a true giant-cell tumor of a tendon sheath was made by Broca, in 1860; he described a lesion on the hand of a twenty-year-old woman. Czerny, in 1869, re-

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 2. Photograph of tumor of Achilles tendon.
Fig. 1-B: Appearance of Achilles tendon at time of operation.

ported a similar lesion on a finger. These early writers called the lesions myelomata or sarcomata. Heurtaux, in 1891, was the first to differentiate these lesions from sarcomata. Tourneux, in 1913, collected from the literature ninety-three cases of tendon-sheath tumors, which he called sarcomata of the tendons sheaths. Only eight of these tumors were on the lower extremities, and none was in connection with the tendo calcaneus. Harbitz classified these growths as real tumors, probably sarcomata of comparatively benign nature. All the later writers, however, agree that the lesions are benign.

Only a few cases of xanthoma of the Achilles tendon have been recorded. Ollerenshaw described an eighteen-year-old girl with xanthomata of both Achilles tendons and xanthelasma on the right arm. He resected the tendons, and he reported no recurrence three years after the operation. McWhorter and Weeks described a negro, thirty-nine years of age, with a blood cholesterol of 600 milligrams, generalized xanthomatous lesions, and involvement of both Achilles tendons. They excised the tendons and reconstructed them with fascia lata. Young and Harris reported a woman of twenty-one with very marked enlargement of both Achilles tendons, which were diffusely infiltrated by xanthomata. These authors also excised both tendons and reconstructed them with strips of fascia lata. Galloway, Broders, and Ghormley, in 1940, reported seventy patients who had a total of eighty-eight xanthomata of the tendon sheaths and synovial membrane. Of the sixty-five patients with tendon-sheath tumors, only four, all females, had lesions in the tendo calcaneus; and in three, the lesions were bilateral. All four patients had xanthomata at sites other than the Achilles tendon,—mainly on the hands and feet.

INCIDENCE

Galloway, Broders, and Ghormley, in an excellent review of the subject, found 274 cases of xanthomata of the tendon sheaths reported in the literature from 1860 to 1938; to these they added sixty-five cases of their own. Jaffe, Lichtenstein, and Sutro, in 1941, reported fifty-five additional cases. The sex and age incidence and the location of these lesions have been similar in the approximately 400 cases thus far reported. About 60 per cent. of the patients were females, and 40 per cent. were males. Tumors of the Achilles tendon, few as there were, were almost entirely confined to females. The usual age was the third or fourth decade, the average being forty years. The youngest patient reported was five years old; the oldest, eighty-two years.

LOCATION

The lesions were two or three times as common in the upper as in the lower extremity. The majority of the tumors were located in the tendons of the wrist and fingers. About 60 per cent. of the tumors in the wrist and fingers were found on the flexor surface, and 40 per cent. on the extensor surface. In the lower extremity, most of the lesions were about the foot and ankle, mainly on the extensor surface. Most of the patients had only a single lesion, but in a few there were multiple tumors in one or more tendon sheaths.

SIZE

There was a wide range in the size of these tumors. Among the largest lesions described were those involving the Achilles tendon. The tumors described by Young and Harris measured twenty-two centimeters on the left leg and fourteen centimeters on the right leg. One of the most extensive lesions found was that reported by Cristol and Gill. Their patient, a man, aged forty-six years, had such an extensive involvement of all the tendons and soft tissues of the lower third of the leg and foot that amputation was necessary. The smallest tumors were found on the fingers, some of these being 0.5 centimeter in diameter. The size of the average tumor in the upper extremity was one by two centimeters; that in the lower extremity was four by five centimeters. In general, the more peripheral the location of the lesion, the smaller was its size.

DURATION

Xanthoma of the tendon sheaths grows rather slowly. The duration of the lesions varied from one month to twenty-eight years, the average duration being about five years. In most cases, there was no pain or disability. The patient sought medical attention chiefly for cosmetic reasons. Pain and interference with function were occasional symptoms, caused by impingement of a nerve or the large size of the lesion.

PATHOLOGICAL FINDINGS

Grossly, these lesions are lobulated, well encapsulated, and have a firm fibrous consistency. They often present a variety of shades from yellow to yellowish brown, which are the result of deposits of lipoid and hemosiderin. The cut surface is hard. Fibrous strands extend from the capsule into the tumor, dividing it into lobules.

Microscopically, certain elements are almost invariably present,—that is, the typical xanthoma or foam cells, stroma cells, giant cells, fibrous tissue, cholesterol, and hemosiderin deposits. The xanthoma cells vary in number in different parts of the lesion. This cell has a foamy or bubble-like cytoplasm, with a small round pyknotic nucleus. The foamy appearance of the cytoplasm is due to intracellular lipoid deposits, mainly cholesterol. The stroma cell, spindle or oval in shape, has a faintly pink homogeneous or slightly granular cytoplasm and a pale oval nucleus. This cell resembles an endothelial cell. A few small globules of fat may be seen in the stroma cells. De Santo and Wilson, by means of fat stains, found various stages of transition of these stroma cells into foam cells. They state that "the foam cells are merely stroma cells laden with cholesterol". Similarly Jaffe, Lichtenstein, and Sutro believe that the stroma cells take up lipoids and become transformed into foam cells and even giant cells. Giant cells vary greatly in number in different lesions. They are essentially phagocytes and they are found mainly near areas of hemorrhage, deposits of blood pigment, or cholesterol. These giant cells resemble those of giant-cell tumors of bone. The nuclei vary in number from five to forty or more. The nuclei are so similar to those of stroma cells that most writers believe that the giant cells are derived from stroma cells, probably from a fusion of the latter.

Hemosiderin is found as yellow or brown particles in all three cell types, mainly intracellularly and occasionally extracellularly. The amount of hemosiderin present depends upon the amount of local hemorrhage and resulting disintegration of red blood cells. Cholesterol and its fatty-acid esters, found mainly intracellularly in the foam cells and to a lesser extent extracellularly (cholesterol clefts), constitute the chief fat content of xanthomata. Ragins states that the cholesterol is liberated by the degeneration of red blood cells, following hemorrhage into the tumor. De Santo and Wilson state that, just as the cholesterol causes the transformation of stroma cells into foam cells, so the hemosiderin changes the stroma cells into pigmented cells (macrophages).

One concludes, therefore, that the three important cell types of xanthomatous lesions are all closely related, and that the stroma cell is the "mother cell" of the foam cell and the giant cell. The stroma cell resembles an endothelial cell and is undoubtedly derived from the reticulo-endothelial system. The affinity of reticular cells for fat and pigment particles was shown long ago by Aschoff and his followers. Anitschkow, one of Aschoff's pupils, produced foam cells by feeding cholesterol to rabbits. He also showed that the same cells which changed into foam cells also took up dyes.

PATHOGENESIS

The nature of xanthomatous lesions of the tendon sheaths has long been a subject of controversy. They have been described as true neoplasms, as inflammatory lesions, as representing reaction to local trauma or infection, and as the result of a disturbed cholesterol metabolism. King, Morton, and Ragins believe that xanthomata are true neoplasms,

which arise from the synovial membrane of the tendon sheath. These tumors, Morton states, are closely related to tumors of joints and bursae. If these lesions are neoplasms, they are certainly benign. As far as the writer knows, there has been no report of malignant degeneration or metastasis from these tumors.

The theory that xanthomata of tendon sheaths are of inflammatory origin was first proposed by Dor in 1898. Later writers supported his views. Mason and Woolston believed that these lesions represent a chronic inflammatory reaction to different irritants. Jaffe and his associates stated that xanthomata of tendon sheaths and synovial membrane represent an inflammatory reaction, the cause of which is unknown. They called attention to the presence of inflammatory elements, such as the phagocytic macrophages, collagen, and hyaline fibers, as evidence of the inflammatory nature of these lesions. They stated further that the inflammatory reaction is caused by neither repeated local hemorrhage nor bacteria. Cultures of the lesions showed no infectious organisms. Lipoid imbalance is also discounted by these authors as an etiological factor.

A disturbance in the metabolism of cholesterol has long been held as the underlying cause of xanthomatous tumors. Pinkus and Pick were the first to call attention to the hypercholesteraemia often associated with xanthomata. They stated that cholesterol infiltration takes place because of an increased cholesterol supply from the blood. Galloway, Broders, and Ghormley are firm adherents of this theory of cholesterol imbalance. They state that the primary factor in the pathogenesis of xanthomata of tendon sheaths and synovial membrane of joints, whether single or multiple, is a disturbance in the cholesterol metabolism. There is either an increase in the absolute value of the blood cholesterol or a change in the ratio of cholesterol to cholesterol ester. These authors believe that the contributory factors in the formation of xanthomata are trauma and infection at the site of the lesion. About 40 per cent. of their patients gave a history of trauma, and 23 per cent. had had local infections.

There are those who believe that hypercholesteraemia is an important factor in the pathogenesis of certain types of xanthomata, but not of all. Stewart divided these lesions into those which were associated with an elevated blood cholesterol and those which were not. Young and Harris differentiated two groups of xanthomata, histologically identical, but clinically different. There is the group described as "xanthoma tuberosum multiplex", in which, in addition to tumors of the tendon sheaths, there are multiple xanthomatous plaques or patches on the skin and on the eyelids. Hypercholesteraemia is almost always present in this group. (The first patient reported here, with a blood cholesterol as high as 800, would belong in this group.) Isolated xanthomata of tendon sheaths comprise another group. Patients with these lesions have normal blood cholesterols. (The second patient described in this paper, except for the slight increase in blood cholesterol, would fit into this group.) Young and Harris considered trauma as an important causative factor in the pathogenesis of isolated xanthomata. This differentiation of two types of xanthomatous lesions reminds one of the interesting analogy drawn by Morton between hypercholesteraemia and xanthomata of tendon sheaths, and hyperparathyroidism and solitary bone cysts.

The writer does not agree with the contention of Galloway, Broders, and Ghormley that an increase in the blood cholesterol or a change in the ratio of cholesterol to cholesterol ester is the primary etiological factor in the pathogenesis of xanthomata. Most patients with multiple xanthomata do have a high blood cholesterol. Rosenthal and Braunisch, however, reported a case of "xanthoma multiplex", in which the blood cholesterol was normal. Patients with isolated xanthomata, on the other hand, usually have a normal blood cholesterol. The cases reported by Mason and Woolston, Ragins, Young and Harris, and Jaffe, Lichtenstein, and Sutro had no increase in the blood cholesterol. It is clear, then, that, whatever the relationship between xanthomata and cholesterol metabolism, a high blood cholesterol is not a prerequisite for the formation of these lesions.

The writer believes that xanthomata are the result primarily of a disturbed cholesterol metabolism. He believes, however, that this is a *local cellular* disturbance, and not a generalized one associated with hypercholesteraemia. Thannhauser and Magendantz were the first to propose the theory of a local cellular disturbance of cholesterol metabolism as the underlying cause for the pathogenesis of xanthomata. They stated that "essential xanthomatosis is a cellular disease of reticulum cells caused by an intracellular disorder of their cholesterol metabolism". This theory of a local disturbance of cholesterol metabolism differs from the hypothesis of a generalized cholesterol imbalance in the concept of a primary intracellular disturbance of cholesterol metabolism, rather than an extracellular excess of the lipoid in the blood stream, causing a secondary deposition of cholesterol in the reticulo-endothelial cells.

Thannhauser and Magendantz classify xanthomatous disease under three main groups: (1) primary essential xanthomatosis, (2) secondary xanthomatosis, and (3) localized xanthoma-cell formation in true tumors. They divide primary essential xanthomatosis into two types,—first, the hypercholesteraemic type, to which belong xanthomata tuberosa of the skin and xanthomata of tendon sheaths; and, second, the normocholesteraemic type, to which belong the isolated osseous xanthomata of the skull and pelvis. This writer would add, to the normocholesteraemic type, the isolated xanthomata of tendon sheaths. Histologically the lesions are the same as in the hypercholesteraemic and normocholesteraemic types. The underlying etiological factor in both of these groups, according to Thannhauser and Magendantz, is an intracellular disturbance of cholesterol metabolism. They state that secondary xanthomatosis, as exemplified by xanthoma diabeticorum, is a symptom of lipaemia. Xanthoma diabeticorum also differs from essential xanthomatosis histologically. In the former condition, there are no foam cells and the cholesterol is *extracellular*. As further evidence in support of their theory of an intracellular metabolic disorder of the reticular cells, Thannhauser and Magendantz point to the formation of xanthoma cells in localized tumors, such as nevoxantho-endothelioma and fibrosarcoxanthoma, lesions which are entirely unrelated to essential xanthomatosis.

Another factor in the pathogenesis of xanthomata of tendons is trauma,—usually not sudden, severe trauma, but rather minor repeated injuries. All of the lesions of the Achilles tendons described here had their origin in the lower part of the heel cord, which is subject to constant repeated traumata from the back of the shoe. The fact that the majority of xanthomata of the tendons are found on the wrist and fingers, which are constantly subject to minor repeated injuries, would also point to the importance of trauma as an etiological factor in the formation of these lesions. Galloway, Broders, and Ghormley found a history of trauma in about 40 per cent. of their cases, and Mason and Woolston found a definite history of injury in approximately 60 per cent. of their patients.

TREATMENT

The treatment of xanthoma of the tendon sheath is excision. Most lesions may be completely removed without interfering with the tendon, but in a few cases where the lesion is large and involves the entire tendon, as in the cases presented here, the tendon must be excised. Recurrences are not uncommon. The incidence of recurrence in the cases reported in the literature has been from 12 to 15 per cent. These recurrent lesions should also be excised. Amputation is rarely resorted to. A few of the recurring lesions respond to deep roentgenotherapy, and this may be used to prevent recurrences; but, in general, roentgenotherapy is of doubtful value. It is used chiefly as an adjunct to surgery, when the entire lesion cannot be removed.

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OSTEOID OSTEOMA

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Seven patients, studied in this Clinic, had bone lesions which clinically, roentgenographically, and histopathologically corresponded exactly to the neoplastic lesion designated as "osteoid osteoma" by Jaffe[3]. All of these patients have now been followed for over two years.

One patient had osteoid osteoma in a rib; this is the first published report of an osteoid osteoma in such a location. A second patient of the authors' series had osteoid osteoma in the calcaneus. A report of this case was published by Jaffe (Case 2) [3] in his original paper on this condition. The lesions in the next two patients were located in the proximal half of the tibia. In the remaining three patients, the bones involved were the middle phalanx of the right index finger, the lower half of the left fibula, and the left ilium, just above the acetabulum.

Three patients of this series were males and four were females. Their ages ranged from fourteen months to twelve years. The patients gave histories of osteocopic pain of slow onset, usually intermittent in character, and not relieved by rest; this pain had been present from three months to one year. These symptoms followed minor traumata in only two cases. If the lesion was in the cortical portion of a bone and was located superficially, an expansion of the cortex of the bone appeared within two or three months after the onset of pain.

On physical examination, a small area of exquisite tenderness could always be detected. In five patients, slight local swelling was present over the elevated and tender area. The patients had no fever, although a slight local elevation of temperature was noticed in two cases. Some limitation of motion and muscle spasm were noted, if the tumor was located close to a joint. Some patients, with osteoid osteomata located in the bones of the lower extremities, had decided limps. Moderate regional muscle atrophy was seen, if the condition was of long standing.

In addition to these general symptoms, peculiar deformities were noted in three patients. The patient with an osteoid osteoma in the posterior end of the ninth left rib (Case 1) had a right C curve of the spine, with marked limitation of motion, and pain and muscle spasm of the left sacrospinalis. A fourteen-month-old child (Case 6) was brought for consultation because of a progressive varus deformity of the ankle, produced by an osteoid osteoma in the lower third of the fibula. In the third patient (Case 4), an inward bowing of the tibia developed due to an osteoid osteoma in the inner aspect of the upper part of the tibia.

The osteoid osteoma appears on roentgenograms as a small nidus-like, circumscribed area (0.5 to 2.5 centimeters in diameter), either uniformly translucent or mottled with irregular and sclerotic bone. It is almost always surrounded by reactive new-bone formation, which is of moderate character when the lesion is located in spongy bone, but which becomes very pronounced when the osteoid osteoma is located in cortical bone. Usually the older the lesion, the more marked becomes this reactive bone sclerosis.

The histological picture of osteoid osteoma is unmistakable, although variations occur in the apparent aggressiveness of its cellular elements. The characteristic appearance is given by an irregular network of partly calcified osteoid trabeculae. Intermingled in this network is vascular and very cellular connective tissue with abundant osteoblasts and

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some osteoclasts. In some cases the osteoblasts and other mesenchymal elements are of normal appearance, but in other cases the cells are big, irregular, and very numerous, with hyperchromatic nuclei which exhibit some mitosis. In the osteoid osteoma of the rib, the reactive periosteal bone was broken through in one area, although there was no invasion of the surrounding soft tissues. The osteoid osteoma is usually sharply demarcated from the surrounding sclerotic bone. Inflammatory cells are absent. Cultures for organisms, performed routinely in connection with the biopsies of these patients, have always been negative. All of the laboratory studies of the blood have also been negative.

Clinically and roentgenographically, the osteoid osteoma appears to be a lesion of inflammatory, rather than neoplastic, origin. This point of view was well elaborated and defended by Mondolfo in 1938 and by Brailsford in 1942. However, the typical histological appearance of the lesion, the complete absence of inflammatory cells, and the negative smear and culture make us believe, with Jaffe, that we are dealing with a benign neoplastic formation. There is no doubt that many cases, presented in the literature as proof that the osteoid osteoma is a lesion of inflammatory origin, are in reality examples of localized low-grade osteomyelitis and not of osteoid osteoma[2, 7].

This series indicates that the treatment of osteoid osteoma must be by an extensive block resection of the lesion, including a large portion of the surrounding sclerotic bone. The tumor and the symptoms have recurred in those patients whose lesions were treated by curettage or incomplete excision. The osteoid osteoma in the phalanx of one of the patients was excochleated twice, and recurred each time. On the other hand, in those patients whose lesions had been totally excised, the tumors did not recur and the symptoms completely disappeared.

Case 1, W. W. A twelve-year-old boy was seen in September 1944, complaining of pain in the lower left thoracic region and inability to straighten up. Both complaints were progressive, and had been present for nine months. The pain was dull and boring in character, and became worse at night. The patient's chest had been immobilized by binding with adhesive tape, which gave no relief. His past history and family history were non-contributory.

Physical examination revealed a long C curve of the spine, concave to the left, with an area of exquisite tenderness over the ninth left rib in the paravertebral area. The pelvis and shoulders were level, and the lower extremities were of equal length and circumference. All reflexes and sensations were physiological.

Two tuberculin tests, an agglutination test for Malta fever, and a Wassermann reaction were negative. The blood counts were normal. The roentgenograms showed expansion of the ninth left rib at the costovertebral junction. There was a central, irregularly dense nidus surrounded by a translucent ring, and some bone sclerosis (Fig. 1-A).

FIG. 1-A

Case 1, W. W. Osteoid osteoma of the ninth rib. Notice C curve and rotation of vertebra.

About five centimeters of this patient's rib was resected in November 1944. The tumor measured 1 by 2.5 centimeters, and was made up of a sclerotic, whitish, irregular bony mass. This was covered by normal-appearing but expanded cortical bone, which was slightly eroded in one small area. There was no gross evidence of inflammation, and cultures were negative (Figs. 1-B and 1-C).

Complete relief of pain was obtained, and the muscle spasm rapidly subsided with subsequent obliteration of the C curve. The patient was seen in July 1946 at the Clinic, and had no symptoms.

Case 2, L. M. An eleven-year-old white girl entered the Hospital on April 21, 1933, complaining of pain and swelling of the right ankle of nine months' duration. Both symptoms followed a minor twist of her ankle, were progressive in severity, and did not improve with rest. The pain was osteocopic in quality,

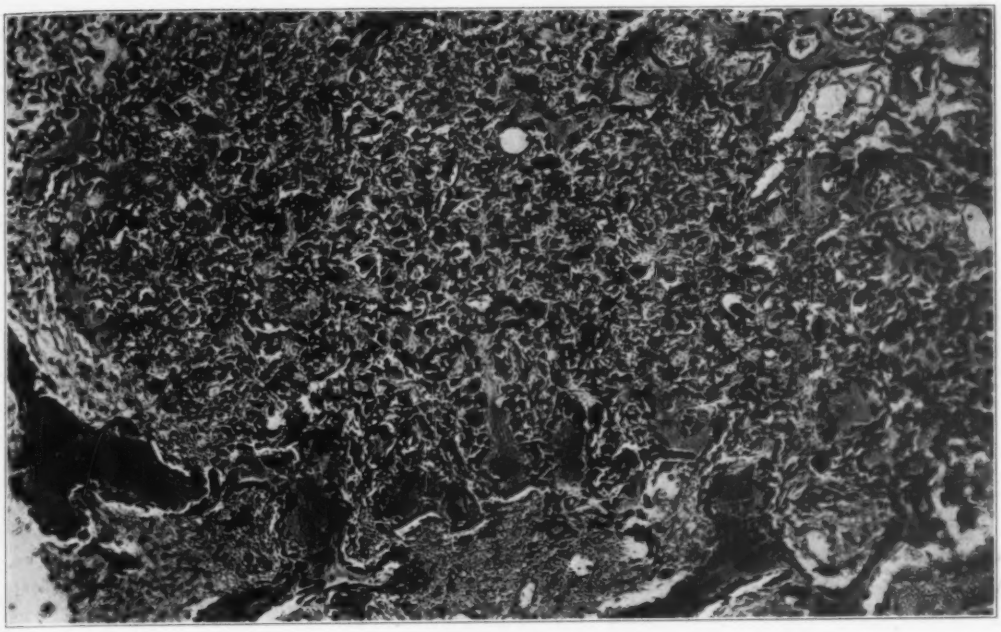

FIG. 1-B

Case 1. The low-power photomicrograph shows a very cellular osteogenetic connective tissue and osteoid trabeculae forming the nidus of the osteoid osteoma of the rib. The periosteal bone is broken, but the tumor does not penetrate it.

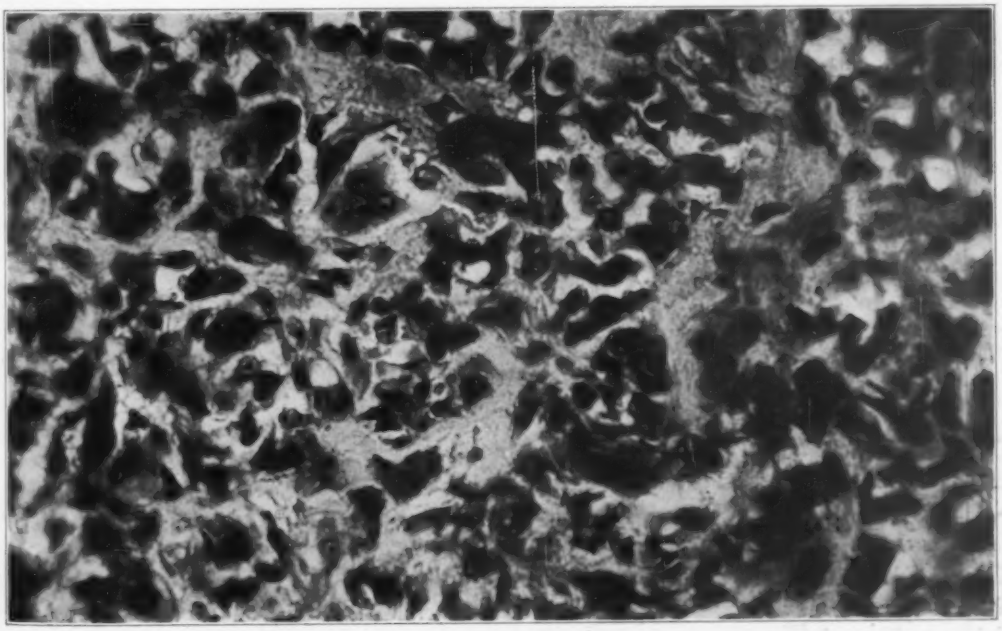

FIG. 1-C

Case 1. The high-power photomicrograph shows irregular osteoid trabeculae, and atypical and hyperchromatic cells.

and sedatives were required for sleep. Her past history and family history were non-contributory. Physical examination showed a diffuse swelling of the right ankle and hind part of the foot. There was atrophy of the thigh of five-eighths of an inch, and calf atrophy of three-quarters of an inch. The patient's range of ankle motion was limited, by pain and muscle spasm, to 10 degrees of dorsiflexion and 10 degrees of plantar flexion. Maximum tenderness was present over the sinus tarsi.

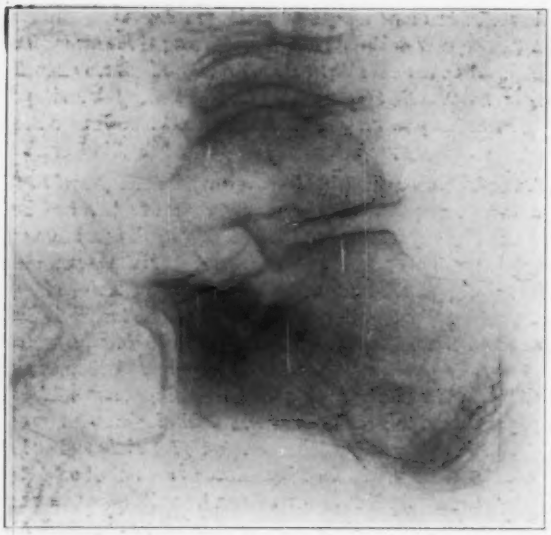

FIG. 2-A

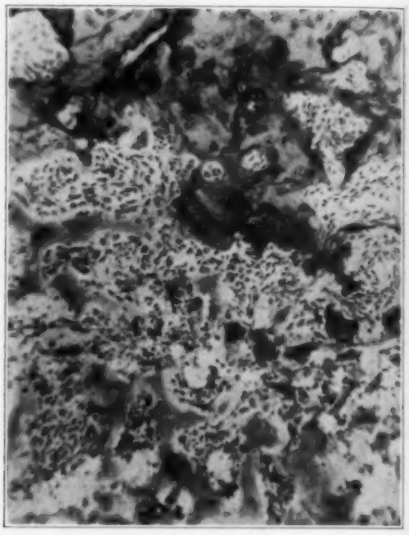

FIG. 2-B

Case 2, L. M. Roentgenogram and photomicrograph of an osteoid osteoma of the calcaneus. (*Fig. 2-A reproduced by permission of American Medical Association from Archives of Surgery*[3].)

The tuberculin test and a Wassermann test were negative. Blood counts were normal. Roentgenograms showed a lesion in the anterosuperior portion of the calcaneus with a dense central nidus, surrounded by a translucent ring and a zone of reactive bone sclerosis (Fig. 2-A).

The lesion was considered to be inflammatory. At operation on May 1, 1933, the cartilage over the anterosuperior surface of the calcaneus was found to be eroded, and the underlying bone was dark red. No pus was encountered. The lesion was curetted out and the wound was closed, but no relief was obtained. Subsequent roentgenograms revealed that the lesion was still present. A block resection, with fusion of the subtalar joint, was done on November 11, 1935. A sclerotic area was seen in the anterior portion of the calcaneus. The

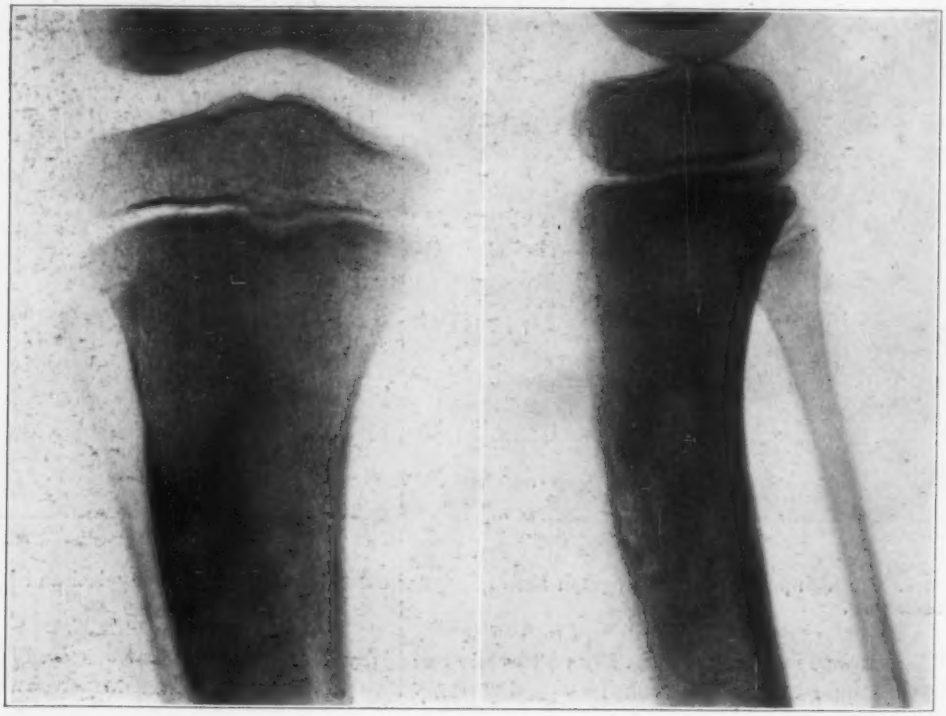

FIG. 3-A

Case 3, F. S. M. Roentgenograms of an osteoid osteoma of the tibia.

bone was very hard and the marrow was evidently fibrous. Complete relief of pain was obtained. The histological picture of the material obtained at both operations was identical, and revealed a typical osteoid osteoma. The patient was last heard from in November 1937, and was entirely free of symptoms.

FIG. 3-B
Case 3. Section of gross specimen removed.

Case 3, F. S. M. An eight-year-old boy entered the Hospital in November 1940, complaining of dull, boring, intermittent pain just below his right knee, which was worse at night. This pain had been present for three and one-half months, and was increasing in severity. There was no history of trauma. His past history and family history were non-contributory.

Physical examination disclosed a slightly swollen, hard area in the upper third of the right leg, over the lateral border of the tibia. There was exquisite tenderness to the right of the tibial tubercle, with a sense of increased heat in this region. Atrophy of one-half inch was noted in the right thigh. The patient's gait was normal.

The tuberculin test and Wassermann test were negative. Blood counts were normal. Roentgenograms disclosed a translucent, irregular area in the anterolateral cortex of the tibia, surrounded by a zone of bone sclerosis (Fig. 3-A).

The lesion was considered to be inflammatory, and the Orr method of drainage was carried out in November 1940. Dense sclerotic bone, with a small area filled with a putty-like substance, was found. Smear

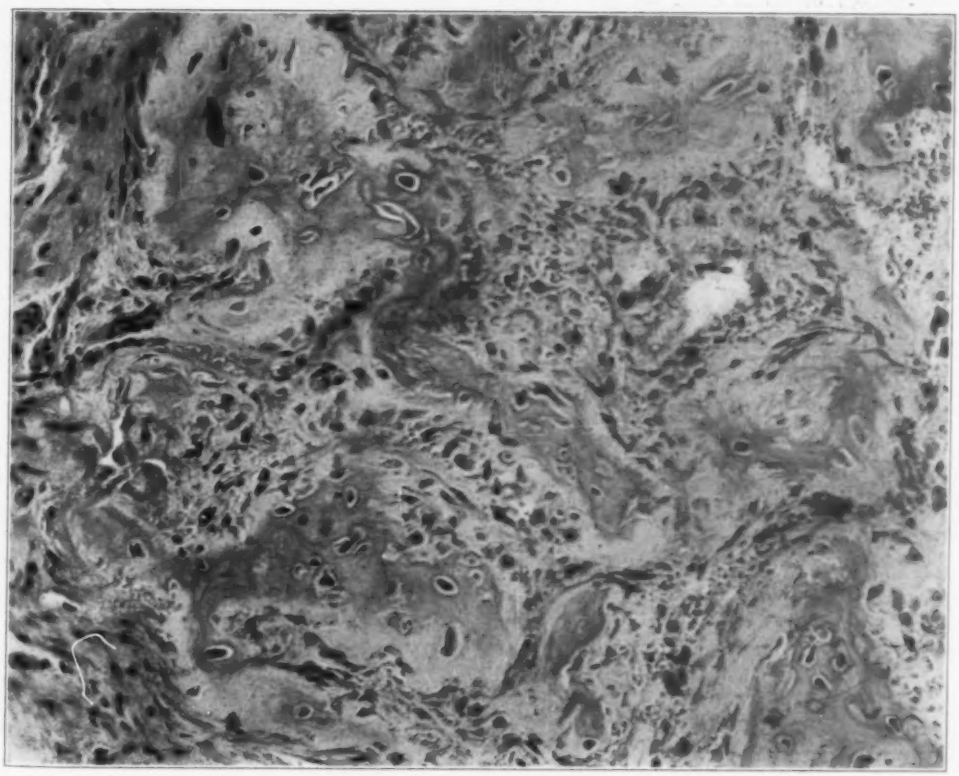

FIG. 3-C
Case 3. Photomicrograph of specimen shown in Fig. 3-B.

and cultures were negative. The pain was not relieved, and subsequent roentgenograms showed that the process was still present. A block resection was performed in May 1942. This block was formed of markedly sclerotic cortical bone, with a central nidus of softer, irregular bony material. Cultures and smear again were negative. A typical osteoid osteoma was discovered during the microscopic study of the material obtained at both operations. Complete relief of pain was obtained after the second operation. The patient was last seen in June 1946, and was entirely free of symptoms.

Case 4, D. S. A two-year-old girl was seen on April 21, 1933. Her parents stated that she had been restless and had had a lump on her left leg for one year. These symptoms were progressing. For the last six months the child had limped after her afternoon nap until she "limbered up". Her past history and family history were non-contributory.

Physical examination disclosed a fusiform, uniformly hard swelling over the upper third of the anteromedial aspect of the left tibia. There was slight increase of local heat, but no discoloration. Atrophy of one inch was present in the left thigh. The patient had free and painless motion of the hip, knee, and ankle. There was a medial bowing of the tibia.

The tuberculin and Wassermann tests were negative. Blood counts were normal. The roentgenograms showed a cortical nidus with a wide zone of reactive sclerosis on the anteromedial surface of the upper third of the left tibia (Fig 4-A).

The lesion was considered to be inflammatory. An Orr drainage was performed on May 1, 1933. The bone was sclerotic and no pus was obtained. Smear and culture were negative. Pain was relieved for one year, and then recurred. Subsequent roentgenograms revealed that the lesion was still present. A block resection of the area was done on June 4, 1934. A cavity containing a fingernail-sized "sequestrum", but no pus, was encountered. Examination of the pathological specimen disclosed the supposed sequestrum to be an osteoid osteoma. Complete relief of pain was obtained after the second operation. The patient was last heard from in March 1946, and had no symptoms.

Case 5, P. J. B. A nine-year-old girl was seen in May 1942, complaining of a painful enlargement of her right index finger of one year's duration. The patient stated that there had been very little pain at first.

FIG. 4-A

FIG. 4-B

Case 4, D. S. Roentgenogram and photomicrograph of an osteoid osteoma of the medial aspect of the tibia. Notice the medial bowing of the tibia.

During the previous five months, however, the pain had been dull and boring in character and progressive in severity, being worse at night. Her past history and family history were non-contributory.

Physical examination disclosed a hard, fusiform, tender enlargement over the distal portion of the proximal phalanx. There was no increase in local heat. Full motion of the finger joints was possible. The tuberculin and Wassermann tests were negative. Blood counts were normal. The roentgenograms revealed a dense central medullary nidus, surrounded by a translucent circle and a zone of bone sclerosis (Fig. 5-B).

An excochleation was done on May 18, 1942. The cortical bone was very hard, and the distal half of the marrow cavity was filled with a dense yellowish-white, irregular bony mass. No pus was encountered. A smear and culture were negative. Examination of the pathological section revealed a typical osteoid osteoma. The lesion and pain recurred shortly after the patient left the Hospital, and on August 10, 1942, she was operated upon again. A soft pinkish mass, which proved to be a recurrent osteoid osteoma, was removed from the medullary cavity. The patient was last seen on July 23, 1946. She has had no osteocopic pain since the second operation. The finger remained enlarged, however, and the patient has pain over the tumor with weather changes. Slight tenderness persisted upon compression of the mass. The roentgenograms revealed that the process was still present. Further surgery was advised, but was refused at that time because the patient was moving from the state.

Case 6, J. S. G. A fourteen-month-old girl entered the Hospital in March 1942, with a deformity of her left ankle which had been present since she began to walk, at the age of ten months (in November 1941). She had pain when shoes were tried on. Her past history and family history were non-contributory.

Physical examination showed lateral bowing of the lower thirds of the tibia and fibula. The patient complained when pressure was made over the fibula, just above the ankle joint. There was no increase in local heat, and no muscle weakness could be elicited.

Laboratory examinations revealed negative tuberculin and Wassermann tests. The blood counts were normal. Cholesterol determinations were 148 and 168 milligrams per 100 cubic centimeters. The total lipids were 811 milligrams per 100 cubic centimeters, and the lipid phosphorus was 5.4 milligrams per 100 cubic centimeters. Roentgenograms showed a translucent area in the lower part of the fibula, with varus of the lower parts of the tibia and fibula (Fig. 6-A).

A two-inch section of the fibula, one-half inch above the distal fibular epiphysis, was resected and osteotomy of the tibia was performed in July 1942. Grossly the lesion showed fusiform swelling and thinning of the cortex to eggshell thickness. On transection, an irregular cavity was found, filled with whitish calcareous tissue. The patient was last seen in May 1946. Her legs were equal in length, no deformity was present, and she had had no symptoms since the operation.

FIG. 5-A

Case 5, P. J. B. Photograph of hand on admission in 1942.

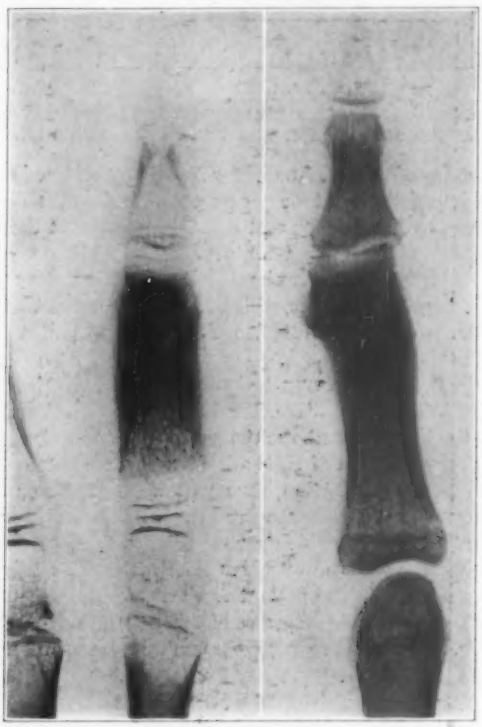

FIG. 5-B FIG. 5-C

Fig. 5-B: Roentgenogram on admission.
Fig. 5-C: Roentgenogram taken in July 1946. Notice that the nidus is still present.

FIG. 6-A

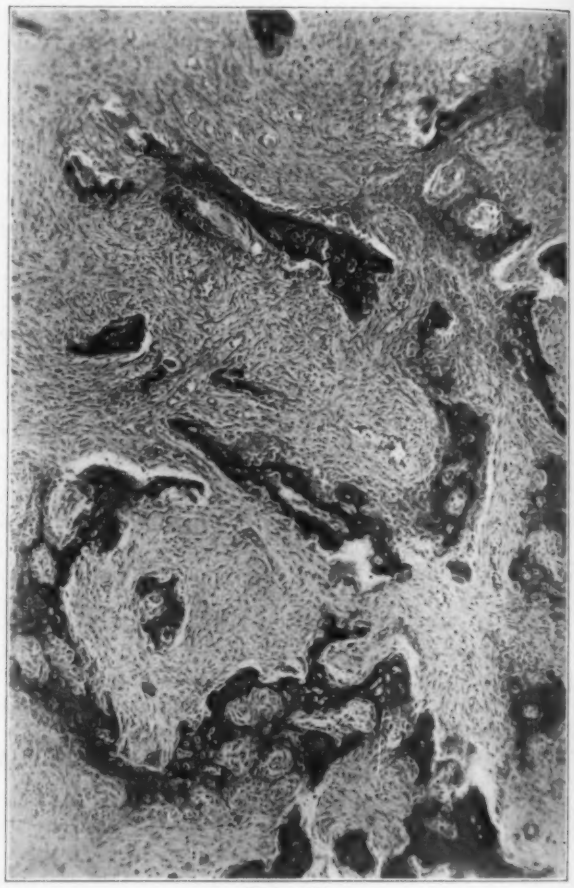

FIG. 6-B

Case 6, J. S. G. Roentgenogram and photomicrograph of an osteoid osteoma of the distal end of the fibula. The photomicrograph was taken from the periphery of the nidus. Notice the abundance of fibrous tissue.

Case 7, D. W. An eight-year-old boy entered the Hospital in January 1936, complaining of intermittent and progressive osteocopic pain of eight months' duration in the left hip. The patient stated that he fell down several cement steps and injured his groin at the onset of his present illness. His past history and family history were non-contributory.

Physical examination disclosed a slight, very tender swelling just below the lateral aspect of Poupart's ligament. All motions of the hip were painful. The range of motion, however, was complete, except for the absence of external rotation. There were no contractures. Atrophy of seven-eighths of an inch was found in the left thigh.

The Wassermann test was negative. The human tuberculin test, 0.1 cubic centimeters in a dilution of 1 to 1000, was positive. The white blood count was 14,600. The roentgenograms showed a destructive lesion in the ilium, just above the acetabulum, with irregular spotty areas of density. This lesion was sharply outlined by an area of bone sclerosis. The periosteum appeared to be elevated.

A block resection, through a Smith-Petersen approach, was performed in January 1936. At operation, the periosteum over the mass could not be stripped. A walnut-sized grayish-white area of soft, dense cancellous bony tissue, which gave the impression of a porous soapstone, was excised. This mass was well defined, and had a smooth outline of sclerotic bone. The smear and culture were negative. Complete relief of pain was obtained. The patient was last seen in December 1939, and had been completely free from symptoms.

Chest roentgenograms of this patient in May 1936 revealed hilar tuberculosis, which was probably active. Subsequent roentgenograms were interpreted as showing healed hilar tuberculosis.

SUMMARY

Of seven patients seen in the University of Iowa Hospitals, each having an osteoid osteoma, one represents the first published report of this condition in a rib. The ages of the patients varied from fourteen months to twelve years. The main clinical symptom was localized pain of from several months' to one year's duration.

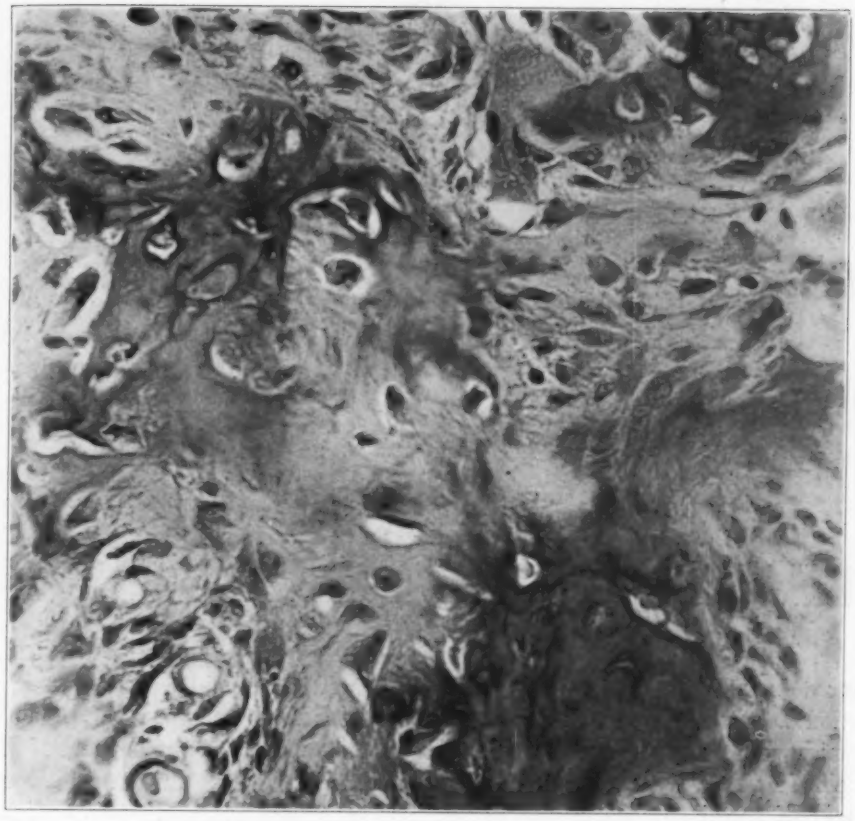

FIG. 7-B

FIG. 7-A

Case 7, D. W. Roentgenogram and high-power photomicrograph of an osteoid osteoma of the ilium. Elevation of the periosteum is shown in the roentgenogram.

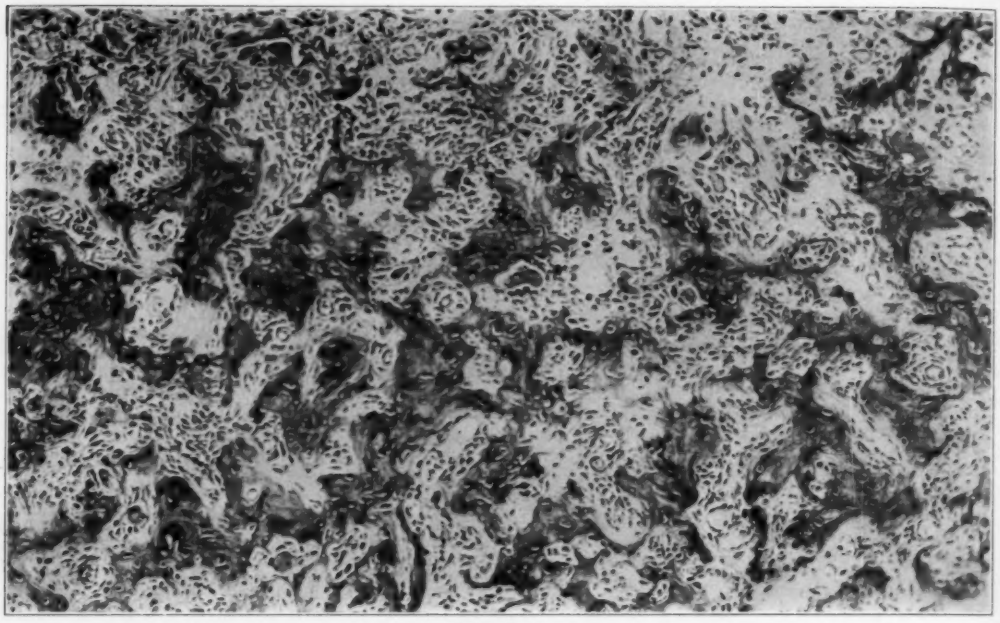

FIG. 7-C

Case 7. Low-power photomicrograph of specimen shown in Fig. 7-B.

Peculiar deformities, produced by the presence of the osteoid osteoma, were noted in three patients. The patient with an osteoid osteoma in a rib had a total C curve of the spine, which improved and finally disappeared after the removal of the lesion. A fourteen-month-old child had a varus deformity of the ankle, produced by an osteoid osteoma in the lower end of the diaphysis of the fibula. The osteoid osteoma in this patient had evidently stimulated the growth of the lower epiphyseal plate of the fibula. An inward bowing of the tibia developed in the third patient, due to an osteoid osteoma in the inner aspect of the upper portion of the tibia.

Mainly because of the typical histological appearance of the lesion, the authors believe, with Jaffe, that the osteoid osteoma is a benign neoplastic formation.

Three patients (Cases 1, 6, and 7) were cured by block resection of the osteoid osteoma and surrounding area. In three patients treated by curettage of the involved area, the lesion recurred (Cases 2, 3, and 4) and had to be resected in a second operation. The osteoid osteoma in the phalanx of one patient was excochleated twice and recurred. The roentgenograms of this lesion have not shown essential changes in over four years.

The authors' experience indicates that the treatment of the osteoid osteoma must consist of an extensive block resection of the lesion, together with removal of a good deal of the surrounding sclerotic bone.

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SOME SURGICAL ASPECTS OF OSTEOID OSTEOMA

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Two patients with osteoid osteoma of the carpal navicular presented themselves at this Army General Hospital for treatment. Since, to our knowledge, osteoid osteoma occurring in the carpal navicular has not been described before in the English literature, the cases were considered of sufficient significance to be reported. Furthermore, the surgical problem in each was different, thus demanding different procedures.

The name "osteoid osteoma" was suggested by Jaffe in 1935, who described several features which he believed were essential to the diagnosis. Although the disease is more common in the long bones, it has also been found in the vertebrae, calcaneus, talus, and other small bones. Roca described a case of osteoid osteoma of the carpal navicular in which enucleation of the entire bone was performed.

CASE REPORTS

CASE 1. A white male, aged twenty-seven, entered the Hospital on January 8, 1945, complaining of severe pain on the radiodorsal aspect of the right wrist. He had sustained mild injury to the wrist in April 1944, while with the Armed Forces. The wrist had been taped for ten days, when treatment had been discontinued. He performed limited duty until November 1944, when he was given a discharge. Heat had been applied with little relief, and pain was severe enough at night to prevent sleep. He had had no fever. Following his discharge from Service, he attempted many different jobs, but was forced to give them up because of pain, redness, and swelling in the radiodorsal aspect of the right wrist joint.

Physical examination was normal, with the exception of the right wrist. On palpation, there was definitely increased local heat and swelling. Even light digital pressure over the carpal navicular caused marked pain. Flexion and extension of the wrist were moderately limited, whereas radial deviation was impossible because of pain. Routine blood and urine studies were all normal. Roentgenograms (Fig. 1-A) revealed an oval area of increased sclerosis, measuring about three by five millimeters, and surrounded by an area of diminished bone density on the radial aspect of the right carpal navicular. The remaining carpal bones appeared normal, and there were no roentgenographic signs of recent or old trauma. It was believed that the area should be explored in an attempt to make a definite diagnosis. On January 20, 1945, a transverse incision in the line of cleavage of the skin on the radial side of the wrist was made. The navicular styloid was identified, and a very short distance from this, the oval area of white bone was encountered. A section was taken for biopsy. It was impossible to enucleate the sclerotic piece of bone with a small pointed periosteum elevator. A sharp chisel was, therefore, used to resect the abnormal bone with the adjacent normal bone in the shape of a triangle. After this pathological area had been removed, it was possible to bring the remaining fragments of the navicular together by gently extending the wrist and with slight radial deviation. The wound was closed with the hand in this position, and a plaster dressing was applied. The patient was hospitalized for approximately one month and then was discharged, but for a period of six months he was seen weekly for reapplication of plaster and periodic roentgenograms. An aluminum wrist splint was then worn for ten months, enabling him to work as a driver for a local grocery concern. Since the operation, he has had no pain whatsoever in the wrist. Roentgenograms taken in June 1946, sixteen months after the operation (Fig. 1-B), show early osseous union of the two fragments of the navicular bone. Immobilization is no longer necessary, and the wrist is now asymptomatic.

The report of the pathological examination was as follows:

Microscopic: "Sections [Fig. 1-C] show a circumscribed area composed of osteoid tissue and atypical calcified osseous spicules. At the periphery, the osteoid tissue is made up of acidophilic bars arranged in an anastomosing, lattice-like fashion. The interstices between these bars contain numerous osteogenic cells, some of which have differentiated into osteoblasts. The lacunae of the bars are large, and most of them are occupied by osteocytes. As the central portion of the lesion is approached, the tissue becomes much more compact with only occasional marrow spaces. Throughout the solid area are bluish-staining areas, representing calcified deposition. The area showing these changes is imbedded in cancellous bone. The surrounding bone exhibits no tendency to sclerosis; in fact, osteoporosis is present. The marrow space contains several

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Preoperative roentgenogram showing area of increased bone density surrounded by area of diminished bone density in right carpal navicular bone.

Fig. 1-B: Roentgenogram June 18, 1946, sixteen months after operation, showing definite osseous union of remaining fragments of carpal navicular.

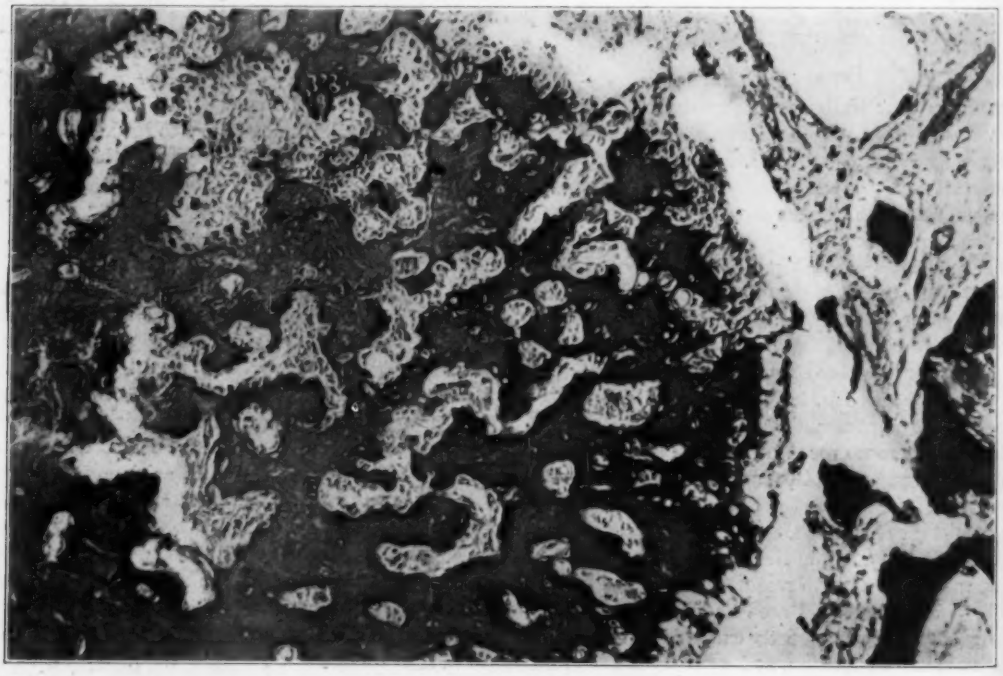

FIG. 1-C

Osteoid tissue predominates microscopic picture.

very thick-walled blood vessels, whose lumina are markedly reduced. In addition, the marrow spaces contain a moderate sprinkling of inflammatory cells.

Diagnosis: "Osteoid osteoma of the navicular bone. (Army and Navy General Hospital accession number S-49-45. A. M. M. accession number 129817.) The culture was negative, as was the smear."

CASE 2. A twenty-two-year-old white male was transferred to the Hospital on February 25, 1945. His history disclosed that for the past two years, there had been periodic pain with slight swelling over the radiodorsal aspect of the right wrist. Prior to induction into the Service, he had sought medical advice and treatment for this condition. He reported to sick call May 27, 1944, and on July 6, 1944, a biopsy specimen was taken from the joint and a spur was removed from the side of the navicular bone. This operative procedure did not relieve the pain.

Physical examination of the patient was negative, with the exception of the right wrist. The scar from the

previous operation was noted. There was mild atrophy of the interossei of the hand. Flexion and extension were nearly normal, but were painful. The right wrist was equal to the left wrist in circumference. Only mild redness could be observed over the carpal navicular region.

Roentgenograms (Fig. 2-A) revealed a circular area of diminished bone density in the distal half of the carpal navicular, which was surrounded on the proximal border by an area of sclerotic bone. Careful comparison with roentgenograms made elsewhere led to the belief that this area of diminished bone density had gradually become larger and more clearly defined.

On March 24, 1945, an approach similar to that used in Case 1 was made. The carpal navicular was identified, and, by making a window in the cortex on the radial side of the bone, the surgeon encountered a definite cavity within the bone, approximately one by one centimeter in size. By the use of a small curette, this cavity was cleaned out. The bone fragments were of unusual softness for normal medullary bone, and, although the color was of the usual red, the material was easily scooped out through the window in the cortex. Inasmuch as this cavity appeared to be almost one third of the size of the entire navicular bone, and there seemed to be danger of a pathological fracture, many chip grafts from the distal portion of the radius were removed and inserted into the cavity. The wound was closed in the usual manner and a forearm plaster dressing was applied. In Figure 2-B, the small radial chip grafts can be seen within the navicular bone. This roentgenogram was made when the cast was removed on April 8, 1945, approximately two weeks after the operation.

The patient was followed for four months and had no pain. There was some stiffness from immobilization, but this gradually diminished. Figure 2-C is a roentgenogram taken on May 26, 1945, two months after surgery, and the previously noted osteolytic lesion is almost completely obliterated by new bone.

FIG. 2-A

Case 2. In the right carpal navicular, there can be seen an area of osteolysis, surrounded by an area of sclerosis. This is most evident on the proximal side.

FIG. 2-B

FIG. 2-C

Fig. 2-B: Fine chip grafts from the distal portion of the radius can be seen within cavity of navicular bone.

Fig. 2-C: Two months following removal of destructive area and insertion of radial chip grafts. The diseased area is now almost completely filled in by new bone.

The pathologist's report was as follows:

Gross: "There are four specimens. The first specimen consists of irregular small fragments of grayish-white and yellowish tissue. The second specimen is made up of two irregular fragments of dense bone. The largest measures seven by five millimeters. The third specimen consists of two small reddish-brown fragments, both of which contain spicules of bone. The fourth specimen consists of five pieces of reddish-brown tissue.

Microscopic: "In sections from the synovia, the synovial villi are more prominent than normal. In many places, the outer coat of synovial cells is lacking. The bulk of synovial villi consists of loose, fibrillar stroma in which are scattered large mononuclears, a rare lymphocyte, and occasionally a polymorphonuclear or plasma cell. Vascularity does not appear to be greatly increased. The capsular tissue contains a few focal collections of lymphocytes. These collections are small and do not possess germinal centers. The collagenized component is normal. The blood vessels show thickening of their walls with reduction of their lumina by intimal connective-tissue proliferation. Sections from the cortex of the navicular bone near the first lesion show a condensation of osseous bars. The osseous bars are invariably marginated by osteoblasts. There is a progressive intensification of osteoblastic activity, passing from the periosteal surface toward the inner margin. The osteogenic proliferation is likewise increased as the center of the specimen is approached. There is nothing to indicate inflammation. The periosteum is thickened by connective tissue and, to a less extent, by osteogenic-cell proliferation. In sections from the rarified area seen on the roentgenograms, the lesion consists of a nidus of densified trabeculae of highly atypical calcified bone. These calcified trabeculae are most irregular, varying markedly in size and shape. They appear to begin nowhere and end nowhere. In other words, they exhibit no definite pattern of mechanical alignment. The calcified trabeculae are separated and surrounded by proliferating osteogenic cells, which, for the most part, have advanced in differentiation to the stage of osteoid tissue. The irregularity of osteoid tissue is striking. Between the osteoid tissue are large numbers of osteoclasts, sometimes applied to the osteoid tissue and sometimes nearly surrounded by osteoid tissue. The osteoclasts vary considerably in size and shape. This osteoid tissue fades into more mature bone.

Diagnosis: "Osteoid osteoma of the navicular bone. (Army and Navy General Hospital accession number S-164-45. A. M. M. accession number 132457.) Smear and culture were negative."

DISCUSSION

In the first case, an osteoid osteoma was suspected preoperatively because of the roentgenograms. The clinical findings were not entirely those ascribed to this pathological entity. The patient had local signs of inflammation,—heat, redness, and swelling.

Of interest was the finding that surgical removal of a portion of the carpal navicular can be accomplished with impunity. The case has been followed for a period of nineteen months; osseous union of the remaining fragments is taking place, and it is probable that the man will have a durable wrist from the standpoint of function, since no arthritic changes have developed in the radionavicular joint.

In the second case, the difference in roentgenographic appearance—namely, osteolysis surrounded by increased bone density—is attributed to a different stage in the evolution of the process. This fact has been pointed out by previous authors. As the process develops, sclerosis of the bone dominates the characteristic roentgenographic findings, whereas earlier osteolysis with bone rarefaction is the rule. In this case, excision of the pathological portion, with the application of chip grafts, rather than excision of the entire navicular bone, was the indicated procedure. Removal of the navicular bone leaves a rather marked incongruity of the joint surfaces, and, if the wrist is used for even mild activity, traumatic arthritis may develop, which in turn may necessitate radiocarpal arthrodesis.

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SUBPERIOSTEAL GIANT-CELL TUMOR

Report of a Case

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Giant-cell tumors occurring in the shafts of long bones are unusual, and few have been reported in the literature. They fall into the so-called "subperiosteal group". The following case does not differ from those previously reported except for the questionable absence of trauma in the history.

W. B., a fifteen-year-old girl, was referred to the Orthopaedic Clinic on March 15, 1945. The patient complained of an aching pain of four months' duration in the region of the right knee. She could recall no injury to the leg. A few weeks after the onset of the initial discomfort, the symptoms became more pronounced, causing her to seek advice from her family physician. A toe-to-groin plaster cast was applied and rest was advised. Eight weeks of this regimen brought no relief. The plaster was removed and roentgenograms were made of the right tibia (Fig. 1). Because of a defect in the upper third of the tibial shaft, the patient was referred to the Clinic.

Examination revealed a healthy young girl with no abnormal findings except in the right leg. Upon inspection and palpation, the right knee joint appeared to be normal with a full range of both active and passive motion. Palpation of the upper portion of the tibial shaft, which was normal in contour, was painful on the medial aspect. This pain was most pronounced about two inches below the condyle. Urine and blood studies were normal. The blood Kahn test was negative. Roentgenograms of the right tibial shaft revealed a well-demarcated, subperiosteal area of bone destruction on the medial surface. A lateral view localized the lesion on the posterior aspect. There was no bulging of the shaft, and no periosteal reaction was present.

By the use of a pneumatic tourniquet, the tumor was explored four days after the original examination. When the involved site had been exposed, a bluish oval area one centimeter by two centimeters was visualized. The cortex was much thinned. The outer wall of the tumor was opened with a small gouge. The tissue beneath was reddish-brown in color and jelly-like in consistency. No membrane was apparent. A routine

Fig. 1

Anteroposterior and lateral roentgenograms demonstrating the lesion to be medial and posterior in the upper tibial shaft.

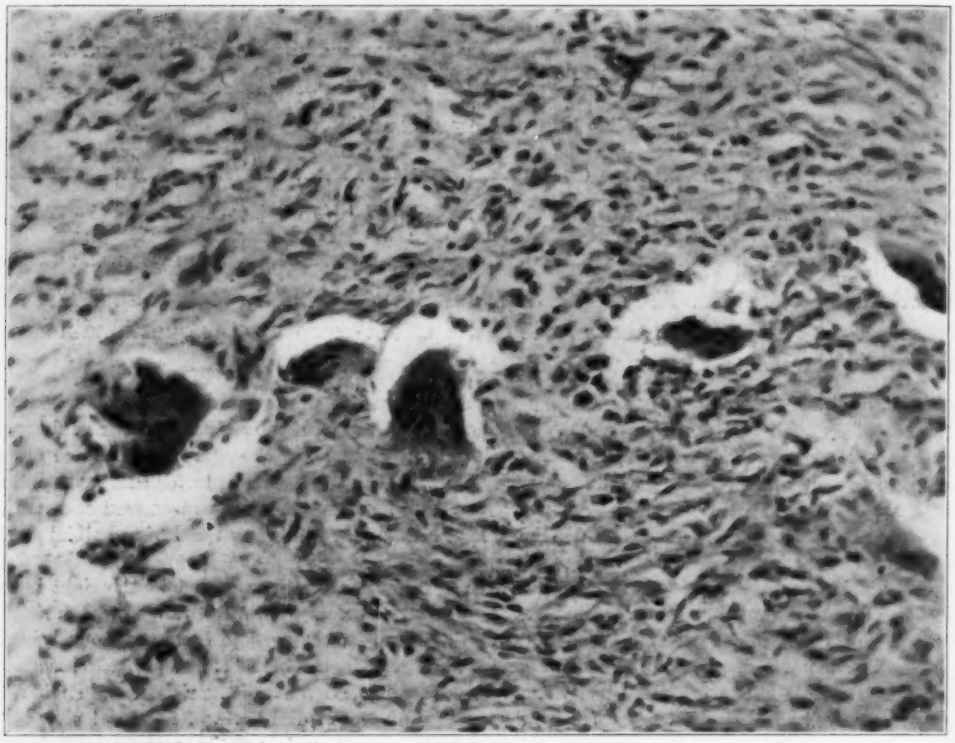

FIG. 2

Photomicrograph (× 260) shows presence of giant cells. (*Negative No. 99261, Army Institute of Pathology.*)

culture was made, and the abnormal tissue was removed. With a small ronguer, the superficial opening was enlarged, and the periphery of the tumor was curetted. Upon irrigation of the defect with normal saline solution, the surrounding bone appeared to be normal. The wound was closed and healed *per primam.*

The tissue was submitted to the laboratories for microscopic examination and the report was as follows: "Examination of tissue submitted showed it to be made up of relatively cellular fibrous tissue, throughout which were scattered numerous multinucleated giant cells. A few spicules of bone were found. These were degenerating and were surrounded by osteoclasts. Some inflammatory cellular infiltration was present. *Diagnosis:* Benign giant-cell tumor. *Culture:* Negative."

The opinion of the Army Institute of Pathology, gathered from a series of slides sent to them, was as follows: "The picture, as seen in these slides, is considered to be one of reaction of bone tissue and bone marrow to injury. It is the consensus of the Staff that this picture differs in several respects from the accepted appearance of a true 'benign giant-cell tumor of the bone'. The giant cells, from which the tumor derives its name, are not nearly so conspicuous as one would wish, and the intervening stroma is composed of spindle cells showing a marked tendency to form collagen. In addition, there are a few areas in which osteoid formation with early calcification suggests regeneration of bone within the 'tumor tissue'. These features, together with the abundant pigment found throughout, suggest a reparative process following an injury, even though no history of trauma can be elicited. The unusual position of this lesion in the diaphysis, close to the cortex, also supports this conception, since the standard type of 'benign giant-cell tumor' is seen only within or near the metaphysis."

Convalescence was uneventful, the patient being seen at regular intervals in the Clinic. In April 1946 (thirteen months after curettage), roentgenograms of the right tibia were made and showed healing with dense cortical bone (Fig. 4).

DISCUSSION

Cone, in 1928, described a case of ossifying hematoma. He called attention to trauma and hemorrhage, pointing out their etiological pathology. At that time, there was a confusion of terms as applied to calcifying hematoma, myositis ossificans, ossifying hematoma, and abnormal osteoclasia.

It is recognized that in this ossifying hematoma, proliferation of osteoclasts is brought

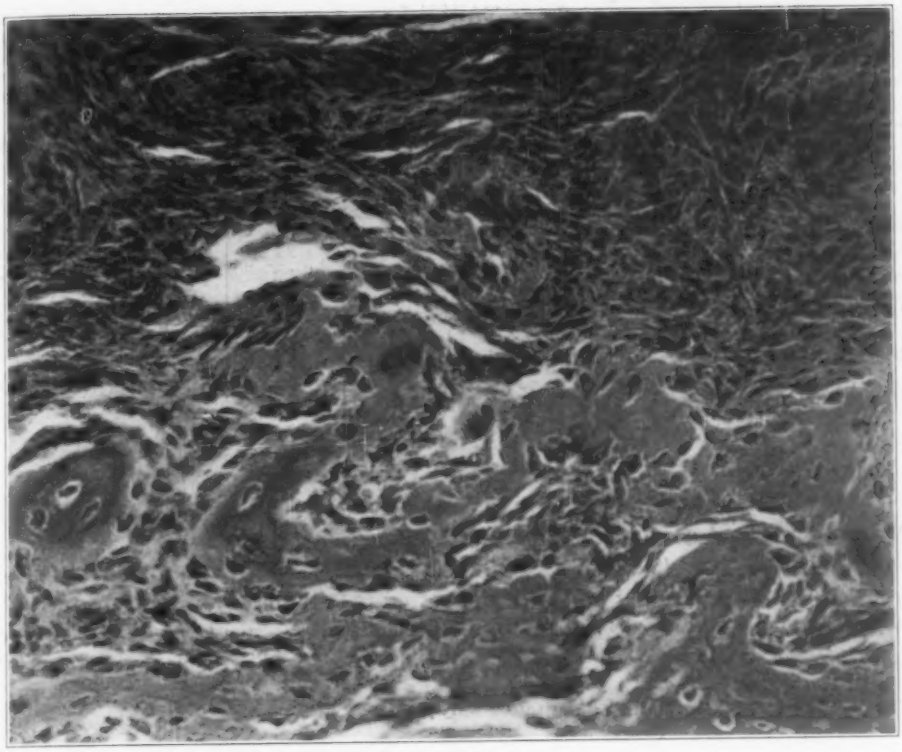

FIG. 3

Photomicrograph (× 320) reveals osteoid formation. There is a good deal of hemosiderin in the fibrous tissue. (*Negative No. 99053 Army Institute of Pathology.*)

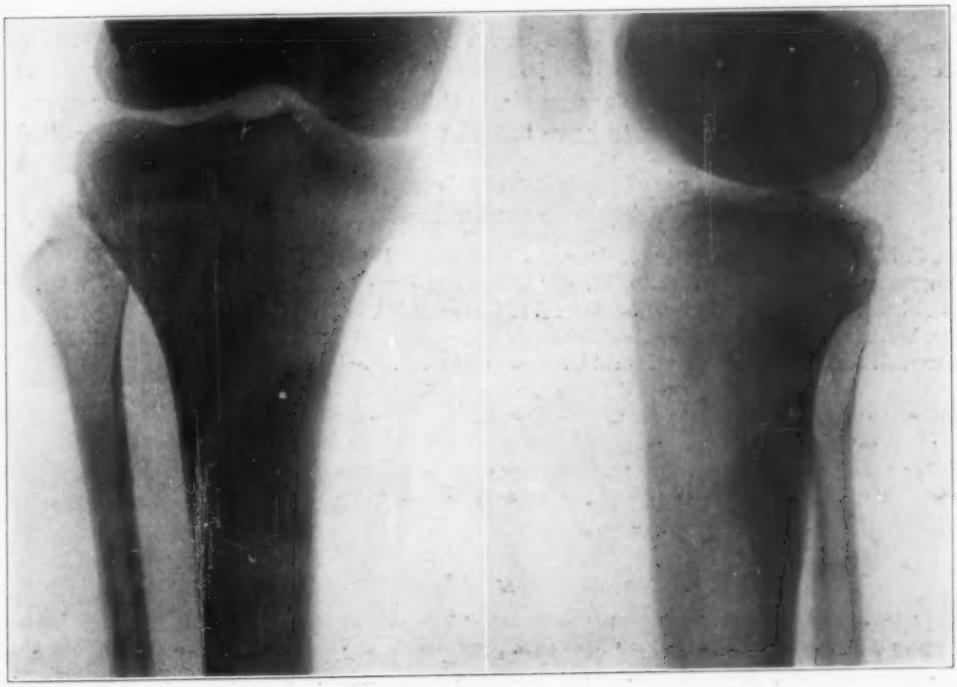

FIG. 4

Anteroposterior and lateral roentgenograms thirteen months following curettage. Healing is seen with dense cortical bone.

TABLE I

REVIEW OF CASES OF SUBPERIOSTEAL GIANT-CELL TUMORS REPORTED IN THE LITERATURE

Name of Author	Location of Lesion	Sex	Age (*Years*)	Duration (*Weeks*)	Treatment
Cone	Upper humerus	F	19	10	Excision
Geschickter and Copeland	Femur	M	17	6	Curettage
Geschickter and Copeland	Ulna	F	21	8	Excision
Geschickter and Copeland	Humerus	F	58	2	Curettage
Geschickter and Copeland	Humerus	F	16	8	Excision
Potts	Mandible	M	6	6	Excision
Present	Radius	M	33	8	Excision
Hodgen and Frantz	Tibia	F	15	16	Curettage

about by hemorrhage and a disturbance of the normal blood supply of the bone, sometimes leading to abnormal osteoclasia or giant-cell tumor. Geschickter and Copeland consider the initial events to be trauma and hemorrhage, followed by separation of the periosteum. In the cortex beneath the periosteum, a disturbance in periosteal blood supply occurs; in the periosteum itself, a healing reaction is stimulated. A mixture of giant cells and osteitis fibrosa results. The underlying cortical bone, however, possesses sufficiently active healing power to overcome any abnormal activity of osteoclasts and causes their rapid regression.

By roentgenogram, these lesions are seen in the diaphysis, casting little or no shadow and appearing as a scooped-out area within the cortex. There may be little or no periosteal reaction and an absence of medullary involvement.

The age group in this type, or variant, of the giant-cell tumor differs slightly from that of the usual epiphyseal type. Table I summarizes the eight cases taken from the limited bibliography.

The case here reported seems to be an example of subperiosteal giant-cell tumor, possessing the characteristics ascribed to this entity. Healing occurred in the cortical bone and was recorded by roentgenograms made thirteen months after the operation. Potts reported the lesion in his case to have healed with no recurrence two and one-half years after treatment by excision.

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OSTEITIS PUBIS

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This relatively infrequent complication of suprapubic prostatectomy was first described by Beer in 1924, who later, in 1928, reported two cases that occurred following suprapubic bladder operations. Muschat in 1945 reported two cases of osteitis pubis and reviewed twenty-three cases in the literature, while Cohen added two more cases in 1946.

The etiology of this condition is not known. Wheeler was unable to reproduce the condition in rabbits experimentally.

Clinical Course

The onset of the condition has been given as varying from ten days to two months after operation. There is usually an insidious, dull, aching pain in the region of the symphysis pubis, which may become localized in either the right or left superior or inferior ramus. The pain may radiate to the perineal region and to the inner aspect of the thighs. Walking becomes increasingly difficult, until the patient is bedridden and suffers excruciating pain when he attempts flexion or extension of the lower extremities. Spasmodic contractions of the adductor muscles may occur on voluntary motion. The duration of the condition varies from about six weeks to as long as two years, as occurred in a patient, reported by Kretschmer and Sights, who had some pain for this length of time.

Diagnosis

The history of a recent suprapubic operation, with physical findings of pain over a localized area of the symphysis pubis, is usually enough to suggest osteitis pubis. Roentgenograms of the areas will prove the existence of the lesion after about the third week. There is a roughening or fraying of the periosteum and a moth-eaten appearance of the symphysis pubes and rami. Decalcification of the rami and inner portions of the ischia may become evident on subsequent roentgenograms. The disease is usually self-limiting with or without therapy, and in about six to ten weeks there is a recalcification and rapid reconstruction of the bones involved. Ankylosis of the symphysis pubis is the rule; otherwise, the bony structures return to normal.

There might be some tendency without roentgenograms to confuse this condition with a simple infection of the space of Retzius or of one of the perivesical spaces. Osteomyelitis of the pelvic girdle from some hematogenous infection, however, gives a different roentgenographic picture, so this condition will not be too confusing.

Bed rest not only is necessary, but the patient will wish to remain flat on his back and to move as little as possible. Body casts may be used; the relief will be complete, slight, or occasionally the condition may be made worse. Recovery is slow and tedious. Drugs — such as opiates, vitamins, and sedatives — and antibiotics may be used to alleviate the distressing symptoms.

CASE REPORT

H. S., a colored male of fifty-one years, was admitted to the Southern Pacific Hospital on September 21, 1943, with the chief complaint of intermittent hematuria of two years' duration. (The patient had been examined by a doctor eleven months before, who found slight enlargement of the prostate. The history was otherwise negative.)

Physical examination revealed essentially normal findings except for the blood pressure—systolic 160 and diastolic 94—and for a slight enlargement of the prostate.

FIG. 1

December 8, 1942. Excretory urogram, made ten months before suprapubic operation, showed good function of both kidneys. The appearance of the bones of the pelvic girdle before operation was normal.

FIG. 2

December 4, 1943. Roentgenogram of the pelvis shows osteitis pubis involving the descending rami of the pubes. Film made fifty days after one-stage suprapubic prostatectomy, two days after readmission. Symptoms had been present for seven days.

FIG. 3

December 15, 1943. Roentgenogram of the pelvis shows no particular change

FIG. 4

January 20, 1944. Roentgenogram of the pelvis reveals good healing with

Blood examination showed:

Red blood cells	4,430,000
Hemoglobin	86 per cent.
White blood cells	5,900
Polymorphonuclear neutrophils	60 per cent.
Lymphocytes	40 per cent.
Non-protein nitrogen	31.5 milligrams per 100 cubic centimeters
Urea nitrogen	13 milligrams per 100 cubic centimeters

Kline and Kolmer tests were negative. The urinalysis showed a specific gravity of 1.010 with albumin four plus and red blood cells four plus. Excretory urograms showed: "Good renal function, bilateral. Flat plate of the abdomen (kidney, ureter, and bladder) essentially negative."

On the day of admission, the patient was panendoscoped under spinal anaesthesia. Bleeding was found to come from a ruptured prostatic varicosity. The prostate was slightly enlarged, and there was a definite contracture of the neck of the bladder. Transurethral prostatic resection was recommended, which was attempted on October 14, 1943. Due to failure of the instrument, a suprapubic operation was necessary. The usual mid-line suprapubic incision was made. The bladder was inflated with about 450 cubic centimeters of fluid through a urethral catheter, and was opened near the dome in the mid-line. An attempt was made to enucleate the prostate, but a complete removal of the gland was not possible, primarily because of the contracture of the neck of the bladder. A 30 cubic centimeter Foley bag catheter was left in the bladder and urethra, and a No. 34 de Pezzer catheter was also left suprapubically. Closure was with interrupted sutures of chromic catgut No. 1. The space of Retzius was drained with a rubber drain. Two grams of sulfanilamide crystals were sprinkled throughout the wound. The skin was closed with continuous sutures of black cotton. The suprapubic catheter was removed on the fifth postoperative day. On November 4, 1943, under spinal anaesthesia, ten grams of prostatic tissue was removed transurethrally, resulting in a complete prostatectomy. The postoperative course was uneventful. The patient was discharged on the fourteenth postoperative day, able to urinate freely and getting up at night only once. The suprapubic wound was healed completely. There was no recurrence of hematuria.

The patient was readmitted to the Hospital in ten days, on December 2, 1943, complaining of severe pain over the symphysis pubis and in the groin. The patient was unable to walk in an upright position and stooped because of pain in the pubic area. There was one hard, indurated lymph gland in the left inguinal region. The report of the roentgenograms (Fig. 2) of the pelvis was: "Descending rami show some irregularity of outline with some suggestion of bone destruction. Otherwise, the pelvis is negative. *Diagnosis:* Osteitis of the pubic bones."

Frequent roentgenograms showed a gradual healing process. Four weeks later, examination showed less periosteal change of the pelvic bones. There was no indication of metastasis. Roentgenograms (Fig. 4) of the pelvis and upper portion of the femur, made on January 20, 1944, showed no evidence of pathological changes of the bones. There was no definite destruction, and good healing was evident. The patient was seen by several orthopaedic consultants, who advised no special therapy except bed rest, small doses of sulfamerazine (fifteen grains three times a day for about ten days), and vitamin therapy. The patient was discharged January 22, 1944, the fifty-first day after readmission to the Hospital, completely free of all symptoms. When last seen on March 3, 1944, seven weeks after discharge, he had absolutely no complaints and considered himself cured.

FIG. 3. December 15, 1943. Roentgenogram of the pelvis shows no particular change.

FIG. 4. January 20, 1944. Roentgenogram of the pelvis, reveals good healing with...

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UNCLASSIFIED PREMATURE CESSATION OF EPIPHYSEAL GROWTH ABOUT THE KNEE JOINT

BY OTTO C. KESTLER, M.D., NEW YORK, N. Y.

Premature arrest of epiphyseal growth about the knee joint, following tuberculosis of the hip, has been described by several authors, including Gill and Zinner and Kestler. However, premature cessation of growth may occur in the epiphyseal plates about the knee joint as a result of hip disorders other than tuberculosis. Early growth arrest in the epiphyseal plates may also occur without lesions of the neighboring joints and without associated lesions being demonstrable elsewhere.[4]

Three types of unclassified cessation of epiphyseal growth about the knee have been observed by the author.

Group I

This group includes infectious hip lesions, producing early secondary growth arrest about the knee.

There is invariably a marked deformity of the knee, with the head of the fibula being prominent in every case. Occasionally there is bowing deformity. A shortening of the entire lower extremity is present, but the shortening is not to be ascribed entirely to the hip lesion, which in some cases produces only minor destruction about the hip. Detailed comparative measurements of the femur, the tibia, and the fibula indicate the actual participation of these bones in the shortening, with the exception of the fibula, which almost consistently continues to grow undisturbed.

Besides tuberculosis of the hip, including one case of bilateral tuberculosis (Fig. 1), pyogenic infection of the hip, caused by hemolytic *Staphylococcus aureus* in childhood, and one case of Still's disease (Fig. 2) have been observed by the author. The distal epiphysis of the femur and the proximal end of the tibia were almost invariably affected by a premature cessation of growth. In most of the cases of this type, marked deformity was present. There was a narrow epiphyseal plate, which was sclerotic in structure, with a star-shaped area in its center. The epiphyseal plate of the fibula was not closed, and the head of the fibula reached the level of the knee joint. Some discrepancy was also noted in the width of the tibia; and, in some cases, the fibula appeared to be hypertrophic. In cases of varus deformity, the medial portion of the tibial epiphysis appeared to be involved. Various degrees of atrophy were always present in the knee joints. The degree of atrophy about the knee joint was always more extensive in cases of tuberculosis of the hip than in cases of other etiology.

Group II

In this group are included non-infectious hip disorders causing or connected with an early cessation of epiphyseal growth about the knee on the same side.

The author observed a baby, eighteen months old, who had been treated successfully for unilateral congenital dislocation of the hip. At the age of three, however, she presented the clinical problem of shortening of the lower extremity (Fig. 3). Detailed comparative measurements, followed by roentgenograms of the knees, disclosed the growth impairment about the knee on the side of the previously dislocated hip.

Group III

This includes cases of premature cessation of epiphyseal growth about the knee, without lesions in the hip on that side and without an associated pathological process being demonstrable elsewhere.

These cases present a shortening of one of the lower extremities. The limp is usually

FIG. 1

FIG. 2

Fig. 1: Fourteen-year-old boy with advanced bilateral tuberculosis of the hip. Note the extensive growth impairment in both knees, with considerable deformity.
Fig. 2: A case of Still's disease, involving several joints and both hips.

negligible, although a sixteen-year-old patient (Fig. 4) with one-half inch of shortening of the tibia had a moderate limp.

A symmetrical uniform flattening of the proximal tibial epiphyseal plate was observed in these cases, combined with abrupt widening of the proximal end of the tibia and increase of the curves of junction of the metaphyseal and epiphyseal portions of the bone. A star-shaped area of increased density in the center of the epiphyseal plate could be seen clearly. No atrophy of the bone was present in these cases. The fibula did not seem to be affected.

The earlier cases, in all three groups mentioned, were observed by the author in the Hospital for Crippled Children, Budapest.

FIG. 3

FIG. 4

Fig. 3: Lower extremities of a three-year-old girl who had a congenital dislocation of the right hip, reduced at the age of eighteen months. Note the changes in growth of the right tibia and fibula at the knee, as compared with those on the left.
Fig. 4: A case of "idiopathic dysostosis of the tibia" in a sixteen-year-old girl with one-half inch of shortening of the right tibia. Patient had no other involvement of the skeleton and no history of a hip lesion. Her only complaint was a moderate limp. Note the early arrest of the upper tibial epiphysis. The head of the fibula is level with the knee joint.

ETIOLOGY

Hip lesions, particularly those of an infectious nature which produce destructive changes in the joint, as a rule bring about premature cessation of the epiphyseal growth distal to the hip joint on the same extremity. The knee joint is most frequently affected. It seems, also, that the greater the destruction and the longer the lesion has been present, as in tuberculosis, the more extensive will be the growth cessation about the knee. On the other hand, the destruction does not have to be extensive to produce marked changes about the knee. Although the etiology is understood in cases of tuberculosis, pyogenic infection, and Still's disease of the hip, the cases in Groups II and III require a searching analysis.

SELECTED CASE REPORTS

CASE 1. A twelve-year-old boy was admitted to the Hospital for Joint Diseases on June 28, 1941, with a history of a fall nine weeks prior to admission. Ten days later, he had pain in the left hip and a temperature of 103 degrees. Three blood cultures were positive for *Staphylococcus aureus*. He was given sulfathiazole and placed in a plaster-of-Paris spica. His condition improved, but a week later the pain recurred and the temperature rose to 104 degrees. The following week the left hip was in a position of moderate flexion, abduction, and external rotation. The left inguinal region and the upper portion of the left thigh were markedly swollen and warm. Several tender lymph nodes were present. Traction was applied, and a blood transfusion was given. Repeated aspirations from the left hip joint produced thin purulent fluid which showed hemolytic *Staphylococcus aureus* on culture. Blood cultures were repeatedly negative. Roentgenograms of the left hip, taken on July 7, 1941, showed irregular necrosis of the superior quadrant of the capital epiphysis, with complete disappearance of the subchondral cortex and narrowing of the joint space. The patient recovered, but at the time of his last admission there was complete ankylosis of the left hip (Fig. 5-A).

The follow-up examination on February 20, 1945 (Figs. 5-B, 5-C, 5-D, and 5-E) showed that the patient was able to walk without assistance. The lumbar lordosis had increased. He had no pain. The left hip was held in neutral position as far as abduction was concerned, but it was in flexion of 150 degrees. The left lower extremity was three inches shorter than the right. There was an overgrowth of the fibula, which projected laterally on the left side with some tendency to varus deformity of the left knee. The length of the right tibia was seventeen and one-half inches; that of the left tibia was fifteen and one-half inches. The distance from the tip of the greater trochanter to the articular surface of the femur was eighteen and three-quarters inches on the right and eighteen inches on the left.

FIG. 5-A

Case 1. Showing complete bony ankylosis of the left hip.

CASE 2. This patient, with tuberculosis of the left hip, was first seen on April 29, 1939, at the age of three and one-half years, in the Out-Patient Department of the Hospital for Joint Diseases. He was treated in a convalescent home by traction, followed by the application of a brace. He was seen in the clinic on December 27, 1944, at which time he was walking with a brace and had no complaints. At the follow-up examination on March 15, 1945, he was wearing a double upright brace on the left lower extremity. The left hip was in abduction of 20 degrees and it was flexed to 155 degrees, in slight outward rotation. There was no motion in that hip. The left lower extremity was three-quarters of an inch shorter than the right; the left tibia was one-quarter of an inch shorter than the right.

FIG. 5-B

FIG. 5-C

Fig. 5-B: Anteroposterior view of the left knee. Note the changes of the upper tibial epiphysis, as compared with the right knee (Fig. 5-D). There is marked atrophy of the femur and tibia.
Fig. 5-C: Lateral view of left knee. Shows marked atrophy.

FIG. 5-D
Anteroposterior view of right knee.

FIG. 5-E
Lateral view of right knee.

FIG. 6-A

Case 2. Roentgenograms of both hips.

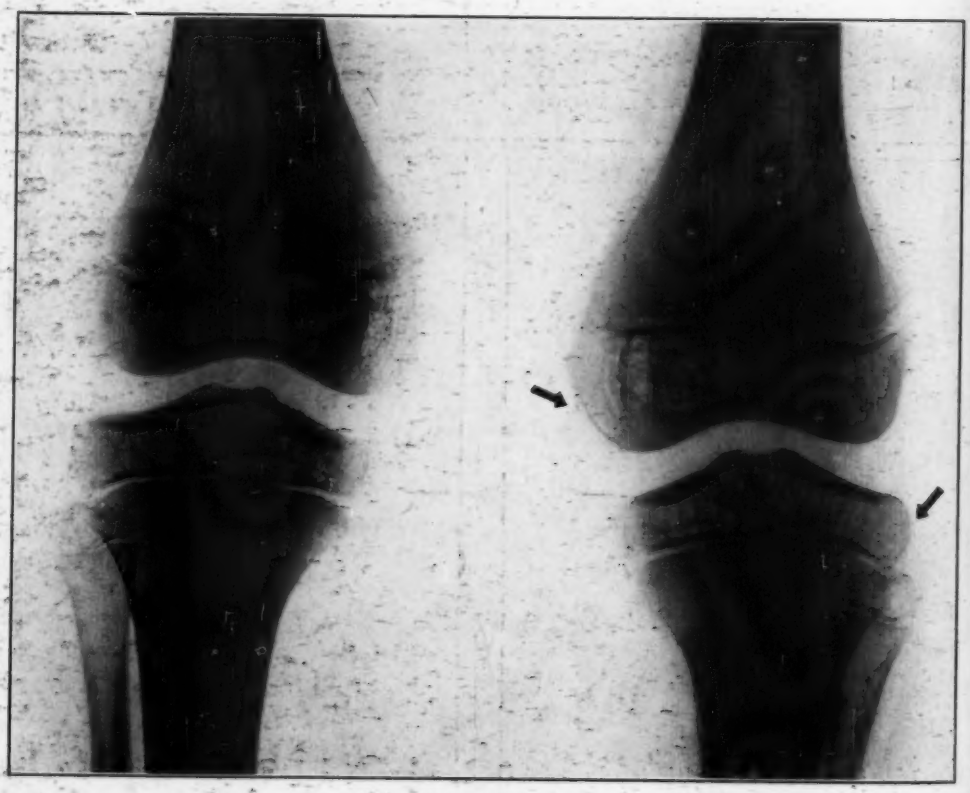

FIG. 6-B

Comparative roentgenograms of the knees. Note that the proximal end of the left tibia is narrower, the epiphyseal plate is smaller and somewhat thinner, and the head of the left fibula is on a higher level than the right. There is also marked atrophy about the left knee.

The last roentgenogram of the left hip, taken on December 7, 1944, showed a fairly old destructive, infectious tuberculous arthritis, with some sequestra. The left fibula was prominent, and there was a tendency to moderate varus position of the proximal end of the left tibia. Roentgenograms of the knees, taken for comparison, disclosed extensive atrophy of the distal end of the femur and of the proximal end of the tibia (Fig. 6-B). There was only a moderate growth arrest of the proximal femoral epiphysis, but the entire tibia was narrower than the right one.

CASE 3. A male, thirty-two years old, was admitted to the Hospital for Joint Diseases on August 27, 1945, because of pain and deformity of the right hip and considerable shortening of the right lower extremity. He had had an injury to the right hip at the age of ten. After that, he was in bed for one and one-half years. Eight years after the injury, a piece of bone was extruded from the right groin, followed by drainage of pus. This condition healed after two years, but the patient had had a limp which had grown progressively worse. On physical examination, the right hip was found to be in flexion of 150 degrees and adduction of 25 degrees; and it was ankylosed clinically. The right half of the pelvis and entire lower extremity, including the femur and the tibia, were found to be underdeveloped. The right lower extremity was three and three-quarters inches shorter than the left. A diagnosis was made of infectious arthritis of the right hip with ankylosis. Marked genu recurvatum was present on the right. Roentgenograms showed underdevelopment of the right pelvis and femur. The hip joint was deformed. The shape of the femoral head had changed completely, and most of it was absent. There was increased density of the acetabulum, and of the head and neck of the femur. Osteoporosis of the right pelvis and femur was seen. The roentgenographic diagnosis was advanced infectious

FIG. 7-A

Case 3. Roentgenogram of pelvis shows underdevelopment on the right.

arthritis of the right hip with considerable new-bone formation (Fig. 7-A). Roentgenograms, taken for comparison, showed retardation of growth of the right pelvis, femur, and tibia. There was an early arrest of growth of the lower femoral and upper tibial epiphyses. The fibula apparently was affected, also, because no deformity was present about the right knee (Fig. 7-B).

FIG. 7-B

CASE 4. A male, twenty-four years old, was admitted to the Hospital for Joint Diseases on November 30, 1945, because of deformity of the left hip with extensive shortening of the left lower extremity. He had had tuberculosis of the left hip since the age of six years, and had received conservative treatment. Upon admission, he had ankylosis of the left hip with a flexion deformity of 145 degrees and adduction of 15 degrees. The left lower extremity was one and one-quarter inches shorter than the right. The measurement from the tip of the trochanter to the lateral condyle of the femur was sixteen and one-half inches on the left and seventeen inches on the right. From the external condyle of the femur to the lateral malleolus was sixteen inches on the left side and sixteen and one-half inches on the right. Roentgenograms of the pelvis (Fig. 8-A) disclosed bony ankylosis of the left hip. They also showed a destructive process, involving the acetabulum and the head of the femur. Increased density was present in these areas. Roentgenograms of the knees, taken for comparison (Figs. 8-B and 8-C), showed impaired growth at the epiphyses on the left side, involving the width of the femur and the tibia. Moderate atrophy of the bones was also noted.

Fig. 7-B: Roentgenogram of right knee. Note the impaired growth of the lower femoral and upper tibial epiphyses, with marked atrophy of these areas.

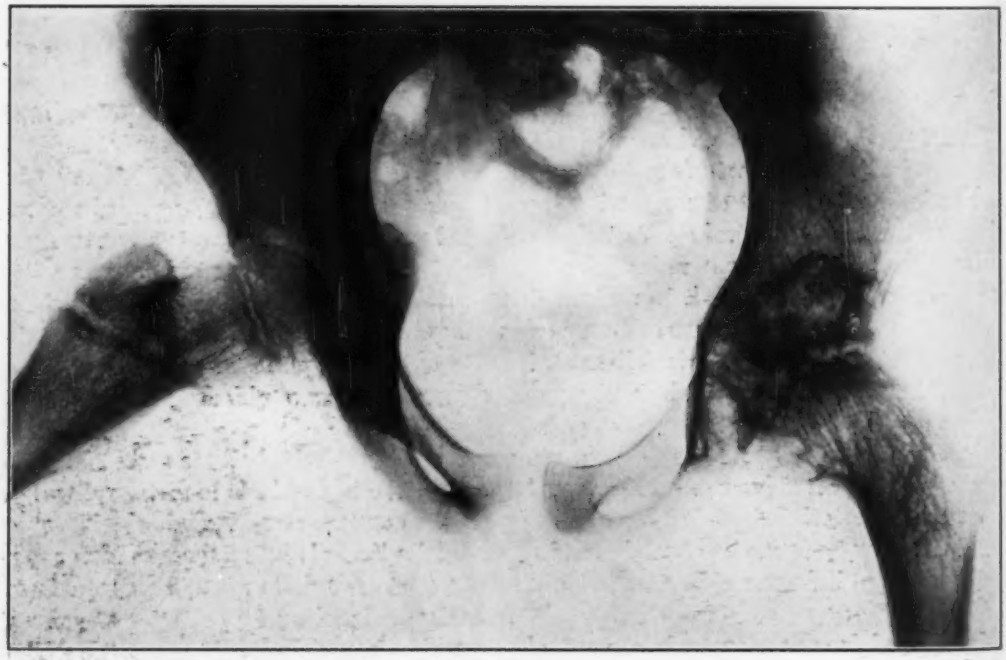

FIG. 8-A

Case 4. Roentgenogram shows bony ankylosis of left hip. Although there is an area of increased density in the acetabulum and in what remains of the head of the femur, there is atrophy of the upper portion of the femur.

DISCUSSION

Although a variety of factors should be considered when early cessation of growth occurs about the knee, either from a neighboring joint lesion or from apparently unknown cause, the author believes that the main factor producing these changes is the impaired blood supply to the growth centers. This impaired blood supply is caused by indirect action, affecting the arteries of the epiphyses; a reflex action explains the distant

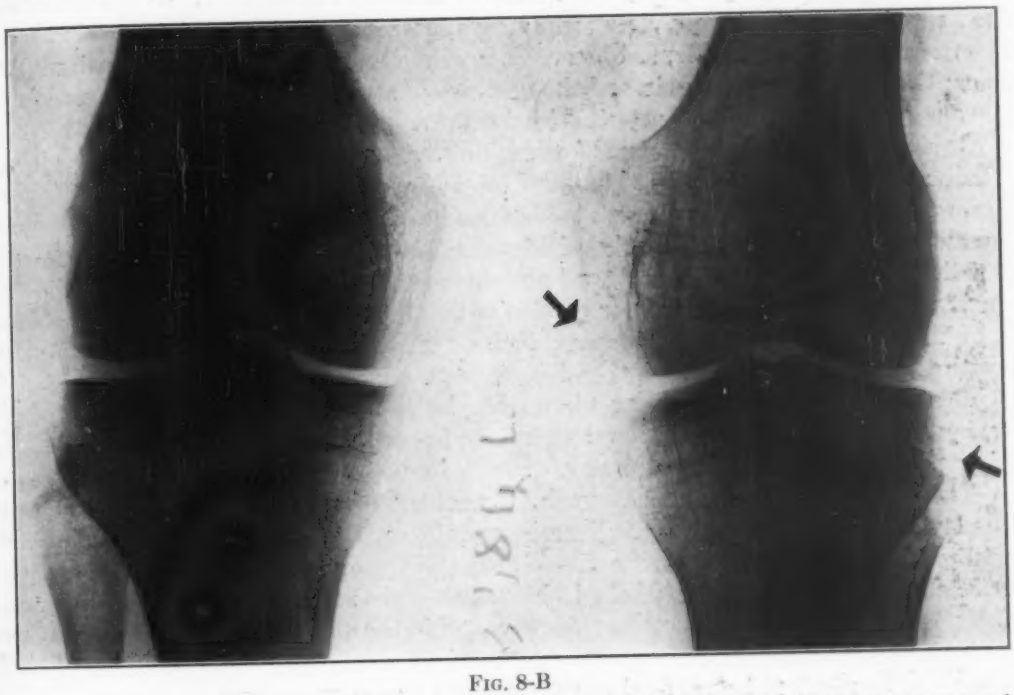

FIG. 8-B

Comparative roentgenograms of the knees. Note the underdevelopment of the left knee as compared with the right, and the extensive atrophy of the bones.

FIG. 8-C

FIG. 8-D

Lateral roentgenograms of both knees (Fig. 8-C, left; Fig. 8-D, right). The marked atrophy is readily seen in these comparative views.

change in the epiphyseal plates. In other words, the writer feels that the theory which tries to explain these changes merely on a mechanical basis is not acceptable.[2]

The periosteal vessels are the main sources of blood supply to the epiphyseal plates. These vessels form an anastomosis with the terminal branches of the nutrient artery[3]. In the writer's opinion, it is the impairment of these periosteal vessels that causes the cessation of growth. It should also be mentioned that the toxins produced by various agents of infection must play an important role. It seems evident that the cutting of the blood supply limits itself to certain areas; the appearance of the star-shaped scar in the center of the epiphyseal plate, as observed on certain roentgenograms, substantiates this assumption. The absence of pain and the presence of atrophy may be cited in support of the conception of an impaired arterial blood supply.

It is conceivable that in Group III, where no obvious changes in the neighboring joints or bones were present, a transient hip lesion might have been responsible for the cessation of growth. Various infectious diseases in childhood can cause the epiphyseal plate to cease to proliferate and to become heavily calcified. In this process, the changes are reversible: Growth is resumed, and a line of arrested growth appears as a scar in the metaphyses of the long bones, particularly in the upper portion of the tibia and the distal metaphyses of the femur[3]. In the author's opinion, however, in cases of localized joint lesions, the secondary growth arrest is irreversible, and, therefore, it produces irreversible growth changes.

Destructive pathological changes in the hip, inflammatory in nature, usually produce varying degrees of atrophy in the lower part of the femur and the upper portion of the tibia, or in both, in the same lower extremity.

There is little doubt that bone atrophy is a contributing factor and that trauma may also play a role; just how much growth arrest may be attributed to these causes is difficult to estimate. In the presence of extensive damage to the epiphyseal plates, it is strongly suspected that the coexisting pathological changes in the hip joint may be due to tuberculosis, in spite of negative laboratory findings and in the absence of biopsy examination. Although this observation has been substantiated by a number of cases, further clinical studies will be required before final conclusions can be drawn.

ADDITIONAL OBSERVATIONS

Since this article was submitted for publication, the author has had the opportunity to observe eight additional cases, bringing the total to twenty-two. The majority of the new cases belong to Group I. The fact that many of the cases in Group I were observed in various age groups, with the onset of the hip lesion at age levels varying between six months and twelve years, permits us to draw the following conclusions: Theoretically, there is a close relationship between the growth centers of the hip and the bones comprising the knee joint. Apparently, whenever the growth centers of the hip are affected by a lesion, the growth centers about the knee joint are disturbed secondarily. This distant growth control probably operates through the perivascular sympathetic chain, as a reflex.

In the cases studied, the distant changes occurred about six to eight months after the growth centers of the hip had been affected by the disease, as evidenced by the roentgenographic findings. However, two or three years elapsed before definite distant growth changes were demonstrated clinically. The peak of the distant growth changes takes place from three to six years after the onset of the hip lesion, and a remodeling takes place according to the law of functional adaptation.

The outcome of this adjustment will depend upon such factors as the original location of the growth arrest (central or eccentric in the epiphyseal plate); the duration of the acute stage of the hip disease; the nature of the lesion (tuberculous, pyogenic, et cetera); the method of treatment; early weight-bearing; and prolonged immobilization.

Distant changes should be watched for during the management of hip lesions, and they should be considered whenever procedures are planned for the equalization of limb length.

NOTE: Because of wartime conditions in Budapest, the original roentgenograms for Figures 1, 2, 3, and 4 were lost. When communications were re-established, the author was told that all the films in the hospital had been used to fill the gaps in the windows in order to protect the patients from the elements, since no glass could be obtained.

A paper containing these illustrations had previously been published privately in Europe, and the prints shown here were reproduced from photographs of these illustrations. The author regrets that the results have not been more satisfactory.

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DIAGNOSIS AND TREATMENT OF RECURRENT DISLOCATION OF THE SHOULDER

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Bankart's method of repair for recurrent dislocation of the shoulder has become widely accepted. It is generally agreed that the pathology of recurrent dislocation of the

FIG. 1-A

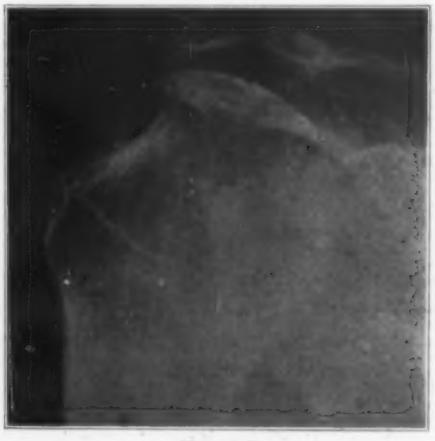

FIG. 1-B

Fig. 1-A: Preoperative roentgenogram, showing irregularity of anterior inferior rim of glenoid cavity, which resulted from anterior dislocations.

Fig. 1-B: Illustrating hatchet-shaped deformity of the head of the humerus in the case of long-standing, recurrent dislocation.

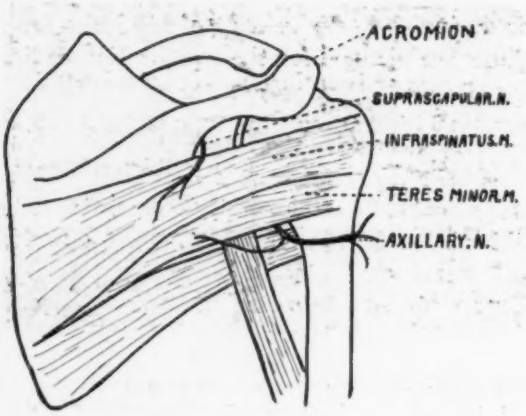

FIG. 2-A

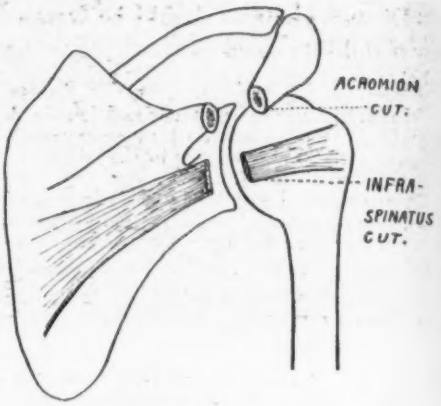

FIG. 2-B

Fig. 2-A: Illustrating structures encountered in posterior approach to shoulder joint.
Fig. 2-B: The acromion has been divided two inches from its tip and the infraspinatus tendon has been divided.

shoulder is a tear of the capsule or an avulsion of the cartilaginous rim from the bony rim of the glenoid. This has been the constant finding when the joint has been exposed adequately. The logic of repairing the actual defect is clear.

In the cases to be reported, a defect in the capsule was invariably found, and Bankart's principle of capsulorrhaphy was used.

DIAGNOSIS

In three of the fifteen cases, dislocation was found to be posterior,—a more common instance than was expected. Differentiation between anterior and posterior dislocation is essential, if the defect in the capsule is to be located and repaired. The history of the mechanism of the original injury may be helpful. Anterior dislocation is caused by a force exerted on the head of the humerus from behind, either directly on the back of the shoulder or indirectly through the elbow. Posterior dislocations are caused by a force exerted on the front of the shoulder directly or through the elbow. The more common dislocations of the shoulder are caused by hyperabduction. They heal readily and do not tend to recur. When recurrence does take place, it is due to the weak inferior capsule. There may be an accurate observation of the dislocation by a medical officer, or the patient himself may be able to

FIG. 3-A

FIG. 3-B

Fig. 3-A: Vertical roentgenogram, showing posterior subluxation of head of humerus.
Fig. 3-B: Postoperative roentgenogram, showing acromion held in position by Kirschner wire.

FIG. 3-C FIG. 3-D FIG. 3-E

Fig. 3-C: Incision of a previous unsuccessful Nicola operation for a posterior dislocation.
Figs. 3-D and 3-E: Illustrating movement of the shoulder three months after posterior capsulorrhaphy.

describe the deformity clearly. Occasionally, the patient may be able and willing to produce the dislocation voluntarily, especially if it is a posterior dislocation. Then the diagnosis is clear. A vertical roentgenogram may be taken for a visual record (Fig. 3-A). Anterior dislocations can rarely be produced at will by the patient. However, roentgenograms may show a defect in the anterior rim of the glenoid or a hatchet-shaped deformity of the head of the humerus. These are the results of repeated dislocations (Figs. 1-A and 1-B). Occasionally, it may be necessary to produce the dislocation again under anaesthesia in order to determine the type with certainty.

OPERATIVE TECHNIQUE

Anterior Dislocation

The operation used to correct anterior dislocation in these cases is almost identical to that described by Bankart. The defect is repaired by suturing the capsule to the freshened rim of the glenoid with three or four interrupted sutures of heavy silk. These sutures are passed through holes drilled in the bony rim. A shoemaker's awl, or a similar instrument, can be used for this purpose.

Posterior Dislocation

The approach to the joint for the repair of the posterior dislocation was originated by one of the authors (R. R.). With an osteotome, the acromion is divided two inches from

FIG. 4-A FIG. 4-B FIG. 4-C

Showing range of movement four months after repair of a posterior dislocation.

its tip and rotated laterally and forward, giving free access to the defect in the capsule (Figs. 2-A and 2-B). If the capsule forms a sac into which the head of the humerus is dislocated, it is opened and plicated snugly. If the cartilaginous rim of the glenoid has been avulsed, as in the anterior dislocation, it is excised and the capsule is sutured to the freshened rim of the glenoid with silk sutures. The sutures are passed through holes drilled in the bony rim, as in the operation for anterior dislocations.

At closure, the infraspinatus tendon is sutured, being plicated if it is redundant. The fracture of the acromion is reduced and fixed by a Kirschner wire inserted longitudinally. The wire is sharpened at both ends, inserted from the fracture site into the lateral fragment first, and then drilled back into the medial fragment (Fig. 3-B).

RESULTS

Fifteen patients—twelve with anterior dislocation and three with posterior dislocation—have undergone operation. All dislocations were originally traumatic with multiple recurrences on such slight provocation as combing hair, putting on an overcoat, swimming, or turning in sleep.

There have been no postoperative recurrences to date in a follow-up period varying from a minimum of seven months to a maximum of eighteen months. All of these patients have been using their shoulders actively without restraint. Thirteen of the fifteen patients are at work. Most of them are engaged in strenuous occupations, such as those of commercial fisherman, hard-rock miner, physical-training instructor, professional hockey player, farmer, and logger.

None of the patients have had serious limitation of motion. As a rule, there has been 10 to 15 degrees' limitation of external rotation and abduction in the anterior dislocation (Figs. 4-B and 4-C), and 10 to 15 degrees' limitation of internal rotation and abduction in the posterior dislocations (Figs. 3-D and 3-E).

CONCLUSIONS

1. Differentiation between anterior and posterior dislocation is essential.

2. Repair of the actual defect in the capsule as described by Bankart is the logical, most effective, and least disabling method of treatment for posterior dislocation as well as anterior.

NOTE: The illustrations were prepared in the Photographic Department of the Shaughnessy Hospital.

A PROSTHESIS FOR CARPOMETACARPAL AMPUTATIONS

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Since the establishment of Army and Navy Amputation Centers during World War II, the number of possible levels of election for arm amputations has increased. This is due to the increase in the surgeon's knowledge, as a result of a closer relationship between amputation surgery, limb-fitting, artificial limbs, and prosthesis training.

In war casualties, the level of the amputation has generally been determined by the enemy fire. Since the development of the Fitch elbow control, a person with either a shoulder disarticulation or a very short upper-arm stump can use a prosthesis. The Meyer polymatic-gainer elbow hinge has provided the short below-the-elbow stump with a functional prosthesis. A suitable prosthesis is now being made for wrist disarticulations and carpometacarpal amputations. Thus, the time-honored principle of "save as much of the hand as possible" now applies to the entire upper extremity.

In the past, with injuries and destruction of tissue through the carpometacarpal zone, surgeons have been required to perform amputations through the lower third of the forearm. Wrist disarticulation has been objectionable in this type of case, because of the difficulty of fitting a prosthesis. When a standard below-the-elbow prosthesis was fitted to a disarticulated wrist, the total length of the prosthesis necessarily exceeded the normal length of the human extremity. Pronation, supination, flexion, extension, adduction, abduction, and circumduction were also lost.

At the various Army Amputation Centers, thirty-seven wrist disarticulations have been performed. Most Army surgeons favor wrist disarticulation. The principal difficulty has been the development of a suitable prosthesis. Northrop Aircraft, Inc., Prosthetic Division, under the auspices and contract of the Committee of Artificial Limbs of the National Research Council, has developed a suitable prosthesis for use in cases of wrist disarticulation. This device allows excellent pronation and supination, but the remaining motion of the wrist is lost. The length of the prosthesis is similar to that of the normal extremity.

At the Amputation Center of the Mare Island Naval Hospital, disarticulations at the carpometacarpal joints have been made in cases in which there had been loss of tissue distal to that zone. The amputated stump retains a high degree of normal wrist motion. Without a prosthesis, the amputee can accomplish a great deal with his stump, because of its longer length, power, and motion (Figs. 1 and 2).

It is desirable to fashion the stump in a somewhat bulbous shape, with a slight degree of flatness in the postero-anterior aspect. This helps to retain the stump in the bucket. The flexor and extensor muscles which have their insertions in the distal ends of the metacarpals (extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris, flexor carpi radialis, and flexor carpi ulnaris) are sutured together over the carpal bones. This helps the power of flexion and extension of the stump. It is essential to utilize the palmar skin for the stump covering, in order to provide durable skin over the end of the stump.

After the surgical wound has healed, intensive exercise, passive and active, with increasing resistance, is prescribed. Shrinking of the stump is accomplished with an elastic bandage. A plaster reproduction of the stump and forearm is made, and a light plastic bucket and forearm cuff are formed over the plaster reproduction. Polymatic joints are set between the bucket and the cuff at the normal wrist axis, and the coupling for the hook or

FIG. 1

FIG. 2

Fig. 1: Stump in flexion and external rotation.
Fig. 2: Stump in adduction and internal rotation.

FIG. 3

Bucket and forearm cuff.

FIG. 4

Arm cuff, webbing sling, and the polymatic joints between the bucket and forearm cuff have been assembled.

FIG. 5

Completed prosthesis, with hook and cable lanyard attached.

Bucket and forearm cuff.

FIG. 5
Completed prosthesis, with hook and cable lanyard attached.

FIG. 6
Pronation and supination possible with hook.

FIG. 7
Flexion and extension possible with hook.

FIG. 8
Pronation and supination possible with the hand.

FIG. 9
Flexion and extension possible with the hand.

hand is added over the distal end of the bucket (Figs. 3 and 4). A leather cuff for the upper arm is fashioned, and the prosthesis is then assembled and fitted on the patient. A sling of webbing is made around the elbow. The hook and the hand are fitted, and the cable lanyard and sling to the opposite shoulder are aligned and adjusted (Fig. 5). This mechanism is used to operate the hook or hand. The weight of the prosthesis is about one pound, without the hook or hand being attached.

The patient then takes the routine course of training in the use of an arm prosthesis, and must pass a satisfactory achievement test, including automobile driving.

The range of motion of the amputation stump, when fitted with this type of prosthesis, is not so complete as for the normal wrist, but from 60 to 80 per cent. of the normal wrist motion is restored to the amputee. Pronation and supination approach normal (Fig. 6). Flexion and extension are very good (Fig. 7). Circumduction is good. Adduction and abduction are limited, but can be achieved by a manual quarter turn of the artificial hand on its coupling. Power is excellent, and straight lifting is adequate. Normal length is maintained. Performance with this prosthesis, fitted with a mechanical hook, is excellent; and the amputee has better utilization with the hook than a forearm amputee has with a standard prosthesis. This is demonstrated by the higher grades recorded in performance of the achievement test by an individual who has had this type of amputation. By using his remaining normal wrist motion, the amputee can achieve with his hook smoother, faster, and better neuromuscular coordination, closely simulating natural motion.

By making alterations in the standard artificial hands which are available, one of these can be attached to the prosthesis by removal of the wrist section, in order to make a receptacle for the bucket. The utility of the artificial hand is still limited to the function available in it. A cosmetic covering for the hand is provided, and it serves fairly well to hide the amputee's deformity (Figs. 8 and 9).

CONCLUSIONS

1. A new type of prosthesis has been developed, which proves satisfactory for carpometacarpal disarticulations.
2. With this type of amputation, most of the normal function at the wrist is retained, and it can be used in working the prosthesis.
3. The stump, without a prosthesis, is more useful than a forearm stump.
4. As much of the upper extremity as possible should be saved during an amputation.

ROENTGENOGRAPHIC FEATURES OF METASTASES OF A RETINOBLASTOMA TO THE LONG BONES

Report of a Case

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While cases of retinoblastoma reported in the literature are not uncommon, a study of the roentgenographic features produced by their long-bone metastases has not been emphasized. The origin of this tumor has not been absolutely established, but it is quite certain that it arises from the posterior portion of the retina and consists of small, closely packed, round or polygonal cells with large, darkly stained nuclei and scanty cytoplasm. The "rosettes", which are frequently present, are believed to be derived from the early rods and cones, although this is not absolutely certain. Broders emphasizes the fact that the tumor cells arise from the regenerative layers of the epithelium, where the cells have the capacity to reproduce. Parkhill and Benedict believe that, although the ganglion cells of the retina are too highly differentiated to become malignant, the supporting or glial cells do become anaplastic and form malignant tumors. It is their opinion that these cells no longer have the form of glial cells, but that they resemble in appearance the undifferentiated cells seen in the highly malignant tumors of the adrenal glands, known as neuroblastomata.

A case of retinoblastoma of the right eye, with metastases to the skull and long bones, was studied recently. Since this case presented interesting lesions by roentgenogram, it is being reported.

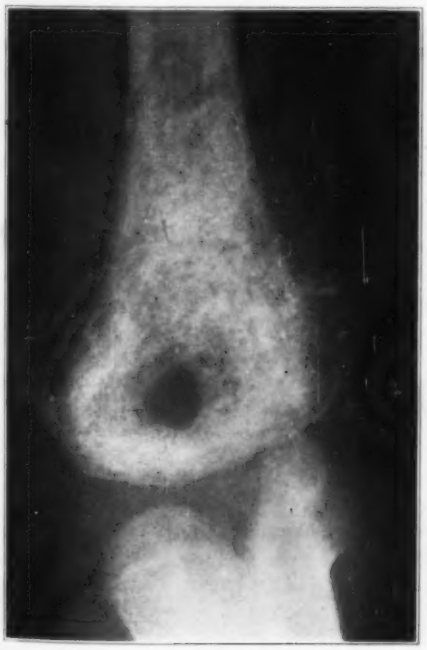

Fig. 1-A

Fig. 1-B

Anteroposterior and lateral views of the right elbow, showing irregular bone absorption and vertical periosteal striations.

FIG. 2

Changes in the upper portion of the left humerus were similar to those in right elbow, but to a lesser degree.

CASE REPORT

A negro boy of six was admitted to the Orthopaedic Service of the University Hospital because of a swelling about the right elbow. The history, as given by the mother, was that the child had fallen and injured his right arm one month prior to his admission to the Hospital. Soon after the injury, the arm was placed in a cast by the family doctor. Shortly after this, the elbow became swollen; fever developed; and it was necessary to remove the cast. The swelling of the elbow continued, and it increased rapidly in size over a period of four weeks prior to admission.

The mother stated that, in October 1944, she had noticed that the patient's left eye was beginning to turn white, and that, in December 1944, it was removed and replaced with an artificial eye. This operation had been performed in a hospital in another state, and a pathological report from that hospital stated that the eye had been removed because of a retinoblastoma.

Physical examination revealed that the child had a firm, tender, fusiform swelling of the lower third of the humerus, about six centimeters in diameter, which, upon palpation, felt definitely warmer than the rest of the extremity. The motion of the elbow was severely restricted and painful. The lymph nodes were enlarged in both axillae; those on the right side were two centimeters in diameter, while those on the left were somewhat smaller. The epitrochlear nodes at the right elbow were also enlarged to a diameter of two centimeters. The only other significant finding was the presence of an artificial eye on the left. The patient's temperature ranged between 100 degrees and 101 degrees by rectum throughout his hospital stay.

Blood examination showed:

Red blood cells	2,130,000
Hemoglobin	5 grams per 100 cubic centimeters
White blood cells	7,400
Polymorphonuclears	59 per cent.
Lymphocytes	31 per cent.
Eosinophils	3 per cent.
Basophils	2 per cent.
Stab forms	5 per cent.

There were nine nucleated red blood cells per 100 white cells counted; and moderate hyperchromia, anisocytosis, poikilocytosis, and polychromatophilia were present. Coagulation time was five minutes, and the bleeding time was nine minutes. The blood Kline test was negative.

Chemical analysis of the blood revealed:

Non-protein nitrogen	50 milligrams per 100 cubic centimeters
Inorganic phosphorus	4.35 milligrams per 100 cubic centimeters
Alkaline phosphatase	4.2 Bodansky units

The urine contained no albumin or sugar.

Roentgenographic examination showed mild atrophy of the lower end of the humerus, swelling of the soft tissues, vertical striations of the periosteum, and irregular areas of bone absorption. New-bone formation was present about the lower three inches of the right humerus (Fig. 1-B). These roentgenographic findings were considered, at the time, to be typical of osteogenic sarcoma. During the examination of other parts of the body, it was found that the upper portion of the left humerus also showed the same type of periosteal new-bone formation with vertical periosteal striations (Fig. 2). Roentgenograms of the skull showed an irregular

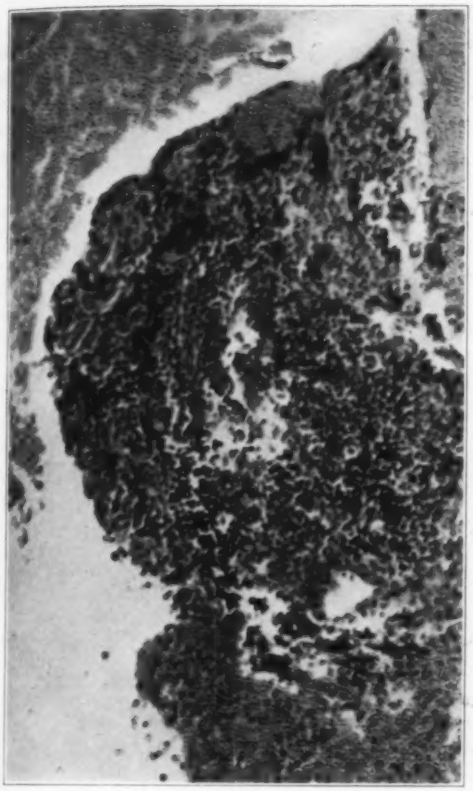

FIG. 3

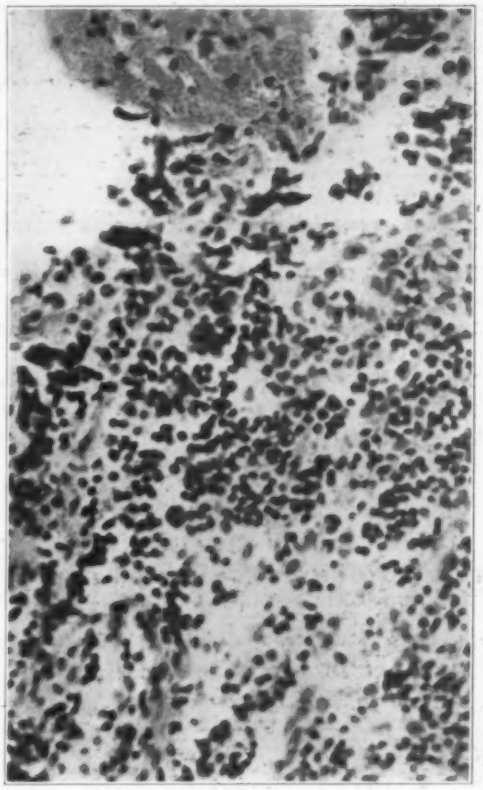

FIG. 4

Low-power and high-power photomicrographs of sections of tumor, showing sheets of round cells with hyperchromatic nuclei and little stroma.

demineralization of the parietal bones. Roentgenographic examination of the chest was negative for signs of pulmonary metastases. No roentgenograms of the lower extremities were made.

A section for biopsy was removed from the tumor of the right elbow and from the epitrochlear lymph nodes. Although this was a very minor surgical procedure, the patient reacted very poorly, and bled so profusely that it was necessary to give him several transfusions to keep him from becoming exsanguinated. At operation, the tumor had a spongy consistency, was beefy red, and was highly vascular.

Histological examination of the tumor showed large sheets of round cells with hyperchromatic nuclei growing without orientation or polarity. Some "rosettes" were present, and there was little stroma in this tumor (Figs. 3 and 4). These findings, together with a history of a retinoblastoma, confirmed by pathological examination, led to the diagnosis of metastatic retinoblastoma of the right elbow. The lymph nodes showed the same reaction.

Treatment consisted of transfusions of whole blood and plasma; 1,500 cubic centimeters of blood and 1,000 cubic centimeters of plasma were given during the patient's hospital stay. He was also given a high-vitamin and high-caloric diet, supplemented by substantial doses of vitamin K. Deep x-ray treatment, totaling 2,000 roentgen units, was given to the right elbow and axilla. However, the patient became progressively weaker, and he died nineteen days after admission.

COMMENT

This case is interesting from the viewpoint of the roentgenographic appearance of the metastases of this tumor to the long bones, which is not an uncommon complication of this disease. Several roentgenologists viewed the films of the right elbow and made the diagnosis of osteogenic sarcoma. However, the finding of a similar lesion in the humerus, with the biopsy findings, led to the final diagnosis. The roentgenographic appearance of the long-bone metastases of this retinoblastoma was indistinguishable from that of an osteogenic sarcoma. Clinically, the unusual youth of the patient, lymph-node metastases, and multi-

plicity of lesions, combined with a normal alkaline-phosphatase determination, would deter one from making a diagnosis of ostoeogenic sarcoma. The literature reveals that little has been written about the appearance of the metastases of a retinoblastoma to the long bones.

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CALCAREOUS DEPOSITS IN SOFT TISSUES ABOUT THE PROXIMAL INTERPHALANGEAL JOINT OF THE INDEX FINGER

REPORT OF A CASE

BY ANTHONY F. DEPALMA, M.D., PHILADELPHIA, PENNSYLVANIA

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The report of this case is prompted by findings in the patient's history which may shed some light on the etiological factors responsible for the presumably unwarranted deposition of calcium about joints. The case recently reported by Vasko[1] is of interest; in fact, the two cases had very similar clinical features and responded to practically the same treatment.

G. T., a man, aged forty-nine, complained chiefly of pain and swelling of the left index finger. The onset was gradual; during the month of March 1946, he had noticed some swelling of the proximal interphalangeal joint of the left index finger. The swelling was accompanied by considerable pain, and motion of the affected joint was restricted. There was no history of injury to the part. The pain was most intense at night, and was aggravated by the slightest motion. During the previous four months, the symptoms had not abated, but rather had become progressively worse.

The past history revealed that, in November 1942, the patient had had a "septic sore throat". This was followed by pain in all the joints of the hands and feet; the spine, knees, ankles, shoulders, and elbows were also affected. The patient had been in the hospital from January 13, 1943, to March 17, 1943. At that time a tonsillectomy had been performed, and he had been treated by autogenous vaccines, the sulfonamides, and blood transfusions. The patient had made a good recovery, and only occasionally (about twice a year) had he had some mild joint manifestations, as pain and stiffness of the small joints of the hands and feet. He had received vaccine therapy for one year. He stated that at no time had his joints been swollen.

The patient was allergic to several kinds of food and pollens. He was under constant treatment for his various sensitivities. He stated definitely that at the time of the onset of the present illness he had no allergic manifestations.

FIG. 1

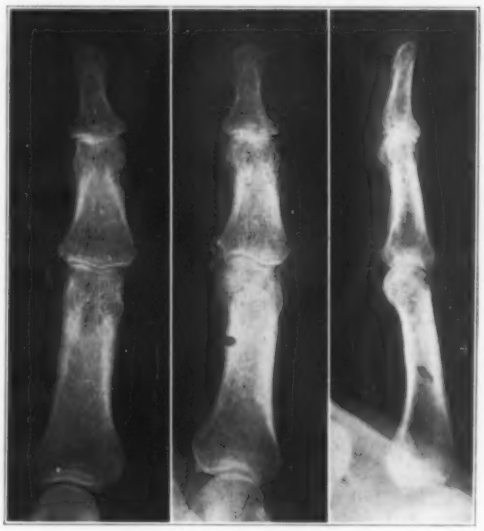

FIG. 2

Fig. 1: Note irregular calcification in soft tissues, especially in the volar and ulnar aspects of the joint. The deposits are amorphous in type.
Fig. 2: Note almost complete disappearance of calcareous deposits after three weeks of fixation and rest.

Physical examination of the left index finger showed it to be uniformly swollen at the proximal interphalangeal joint. The skin was rather taut around the joint. The temperature of the affected part was considerably increased. The finger was held in extension of 180 degrees, and any attempt to flex it, actively or passively, beyond 165 degrees caused severe pain. Palpation showed the point of maximum tenderness to be along the ulnar aspect of the joint.

There were no systemic symptoms, and no other joint was affected. All laboratory tests done at this time, including sedimentation rate, complete blood studies, calcium determination, and uric-acid determination, were within normal limits. Roentgenographic examination revealed irregular calcification, amorphous in type, in the soft tissues on the volar and ulnar aspects of the proximal interphalangeal joint of the left index finger.

Treatment: The finger was put at complete rest by the application of a skin-tight anterior splint of molded plastic. This fixation gave the patient immediate relief; it was maintained for two weeks. At the end of that time, the finger was taken out of the splint several times daily, exercised, and then replaced in the splint. At the end of the third week, all swelling had disappeared, and the range of motion at the affected joint was from 180 degrees to 70 degrees, and painless. Roentgenographic examination at this time showed that most of the calcareous material had disappeared; only a trace still remained in the tissues.

DISCUSSION

This case closely resembles that great number of cases in which there are calcareous deposits in the rotator cuff of the shoulder joint, associated with an acute onset of symptoms. The etiological factors behind this pathological process are still not clear. It is obvious, however, that the local disturbance of calcium metabolism, in these cases, is in response to some other factor. The case suggests that the factor sought for may be either some focus of infection or an allergy. It may well be that, in the presence of one of these two factors, the local disturbance of calcium metabolism in the soft tissues about a joint is the response to a local exciting cause. The exciting cause may be repeated traumata to the affected tissues. Such traumata may readily escape the notice of the patient; frequently no history of injury is obtained. This possibility at least deserves more investigation and experimental study.

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CRYPTOCOCCUS NEOFORMANS INFECTION (TORULOSIS) OF BONE

Report of a Case

BY CLARAN H. JESSE, M.D., LOS ANGELES, CALIFORNIA

From the Orthopaedic Service, Los Angeles County General Hospital, Los Angeles

The first article on Torula infection in man, involving the central nervous system, was written by Zenker in 1861. Since that time, there have been numerous reports of the involvement of other tissues, but it is believed that this is the first report of bone torulosis.

A Caucasian male, twenty-four years old, came to the Hospital on April 12, 1945, stating that his right hip occasionally "came out of place". He was referred to the Orthopaedic Clinic.

The patient stated that pain had suddenly appeared in the right "hip" two weeks before, and he localized it by pointing to the greater trochanter. The pain was described as a "sore feeling", and at times it awakened him at night. He had had several osteopathic treatments, but the pain had not been relieved.

The patient had had the usual childhood diseases, with a questionable history of smallpox. Attacks of epilepsy began at the age of four and continued to the time of examination. He had been treated since January 26, 1945, by members of the Eye Service for a corneal ulcer of the right eye. Urinalysis at that time was normal, and tests with tuberculin No. 1 and No. 3 were negative. A coccidioidin skin test and a Wassermann reaction were also negative. The report of the chest film, taken on January 29, 1945, was as follows: "Hazy and patchy infiltration, most marked in the right lung field and accentuated in the right apex, consistent with pulmonary tuberculosis. The possibility of infection with Coccidioides cannot definitely be ruled out." A second chest film, on March 3, was reported as unchanged. The patient had no clinical chest symptoms or complaints at any time.

Physical examination, on April 12, 1945, disclosed a normal-appearing right lower extremity. The patient walked with a right-sided limp, and thigh flexion was limited to 60 degrees because of pain. Anteroposterior and lateral roentgenograms of the hip were taken, and showed a cyst about two centimeters in diameter in the right inferior pubic ramus (Fig. 1). The hip was normal.

The patient returned on April 24, with the same complaints as on his initial visit. He stated that, as he was walking in the hall, he felt a "snap" in his "hip" and then had more pain. Because of the possibility that a pathological fracture had occurred, a flat plate of the pelvis was ordered immediately. Examination of the wet film showed that the "cyst" was much larger than it had been two weeks previously, and that the lower cortex of the right inferior pubic ramus showed more destruction. The patient was then admitted to the Hospital for further study. Another physical examination showed no additional findings.

Fig. 1

Anteroposterior view of the right hip, taken April 12, 1945, shows the lesion. The cystic area in the inferior pubic ramus can be noted readily.

The following laboratory studies were then made: On May 1, a coccidioidin skin test was negative. The next day, a complement-fixation test for Coccidioides was negative, as was a spinal Wassermann. Roentgenograms of the pelvis, taken on May 12, showed the lesion to be enlarged and the upper cortex of the inferior ramus to be invaded (Fig. 2). The blood count was within normal limits. Roentgenograms of the skull, taken on May 14, showed no bony abnormality. Determinations of blood calcium, phosphorus, and phosphatase were within normal limits.

On May 24, the area was explored, and a specimen was taken for biopsy examination. The area was cystic and contained a reddish-yellow cheesy material, with a little yellowish fluid. A sample of this material was sent to the laboratory for routine smear and culture, and also for examination for acid-fast bacteria. The patient had a low-grade fever before surgery and for several days following it, but his temperature then returned to normal. The smear showed a few polymorphonuclear leukocytes; no pathological organisms were present. The culture showed no growth in forty-eight hours.

The microscopic pathological findings were:

"*Curettings from Bone:* Section is that of granulation

FIG. 2: Showing expansion of lesion by May 12, 1945.

tissue, heavily infiltrated with plasma cells and macrophages. A few neutrophils, eosinophils, and lymphocytes are present, also. Occasional giant cells are seen. There are a few areas of early necrosis with pyknosis and karyorrhexis. A careful search for organisms discloses a few suggestive ones in the giant cells, and occasionally in the intercellular tissue. These are perfectly round and about the size of lymphocytes. A few bits of newly formed bone are present in the periphery of the granulomatous area. Histological appearance is consistent with the diagnosis of torulosis of bone."

The laboratory report stated that *Cryptococcus neoformans* or *Torula histolytica* had been grown on the culture, and that the organism was pathogenic to mice. This organism was not present as a laboratory contaminant. Because the type of organism present was pathogenic to mice, this report coincided with that of the pathologist; and the diagnosis was believed to be definite. Roentgenograms of the pelvis, taken on June 11, showed the lesion to be expanding. A urinalysis was negative, and a seventy-two-hour sputum culture was negative for fungi.

FIG. 3

On August 1, 1946, no further involvement is seen. Thirteen months have passed since complete excision of the involved area. Note the new-bone formation at the superior cortex of the right superior pubic ramus. This area may or may not have been involved, but is healed now.

On June 28, the major portion of the right inferior pubic ramus was removed surgically. Roentgenograms, taken on July 12, showed that all the infected material had been removed. This time the pathologist's report stated that there were a few round cells and occasional giant cells, but that none of the granulomata seen in the previous section were found.

Penicillin therapy was started on June 28, and continued until 1,320,000 units had been given. Sulfadiazine was given for two weeks, with a total dosage of eighty-four grams.

The patient made an uneventful recovery, with complete healing of the soft tissues in the usual time. He was discharged from the Hospital in July 1945, and his condition was followed in the Out-Patient Clinic.

On August 30, 1945, the patient stated that he felt fine and had gained twenty pounds. He wanted to go to work, and was allowed to do so. He was seen monthly, and roentgenograms were taken every two or three months. His only complaints were occasional cramps in the right thigh. He was doing well when last seen, on August 8, 1946. Roentgenograms taken on August 1 showed no further involvement of the chest or pelvis.

AN INSTRUMENT FOR USE IN THE BANKART OPERATION FOR RECURRENT DISLOCATION OF THE SHOULDER

BY MAJOR GEORGE I. REISS

Medical Corps, Army of the United States

It is generally agreed that the Bankart type of repair is the operation of choice in the treatment of recurrent dislocation of the shoulder. The most arduous and time-consuming step in this procedure is the placing of sutures through the osseous margin of the glenoid cavity. In the past, in our experience, the average time required to place these sutures usually has been from one-half to three-quarters of an hour. By using the "suture carrier" described here, the operation can be shortened to at least half the time.

There is a separate suture carrier for each shoulder, shaped in such a manner that the surgeon has good vision of the operative field while placing the suture. Instead of two mattress sutures, suggested by Bankart, four interrupted sutures are placed. The capsule of the shoulder joint is exposed by reflecting distally the common origin of the short head of the biceps, the coracobrachialis, and the pectoralis minor, and by dividing the subscapularis

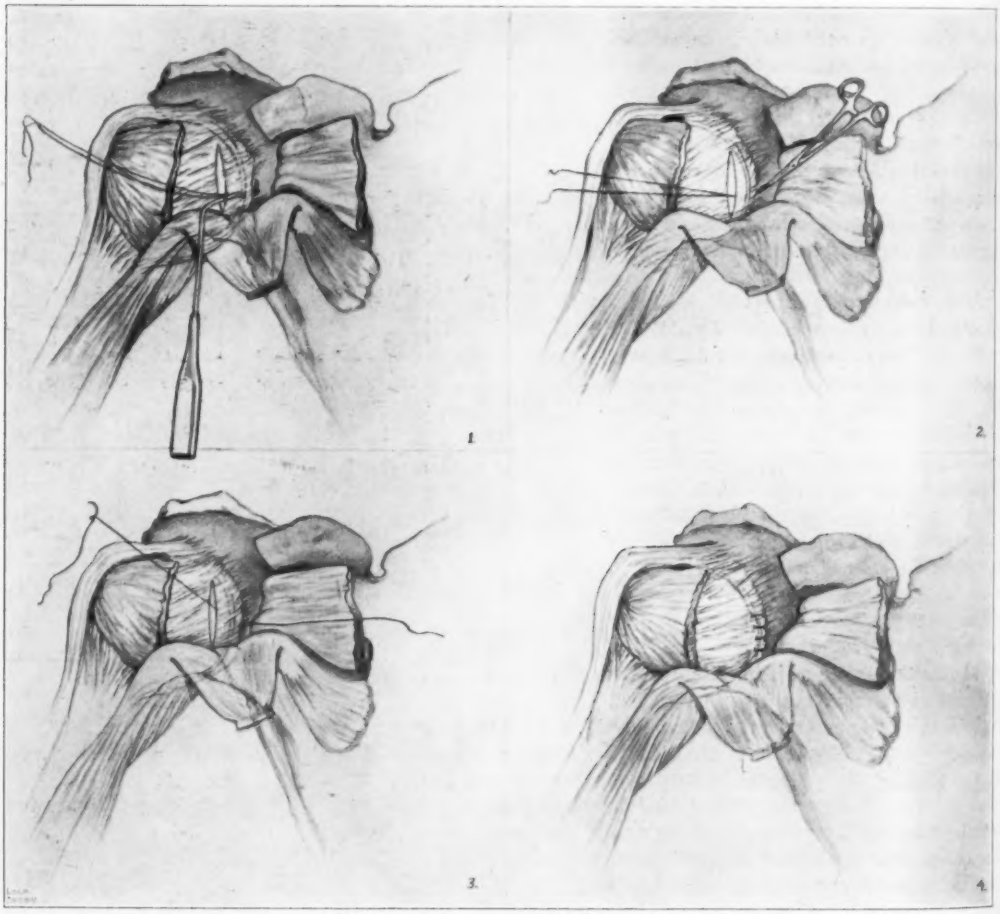

FIG. 1

Drawings show how the hole is drilled and the suture is applied.

one-half inch medial and parallel to its insertion. The capsule is then incised parallel and one-half inch lateral to the glenoid margin. The instrument carrying the suture is placed intra-articularly through the rent in the capsule (Fig. 1,*1*) and, by up-and-down motion, a hole is easily drilled into the osseous glenoid margin. The assistant grasps the suture and the instrument is withdrawn (Fig. 1,*2*).

In Figure 1,*3*, the suture is pictured just before imbrication of the cut capsular edge. A needle, threaded with one end of the suture, then pierces the area of the capsule selected by the surgeon to be sutured to the roughened osseous glenoid rim. Four sutures are placed in a similar manner, and all four are tied (Fig. 1,*4*). The instrument described here was used in the repair of nine shoulder joints for recurrent dislocation, according to Bankart's procedure.

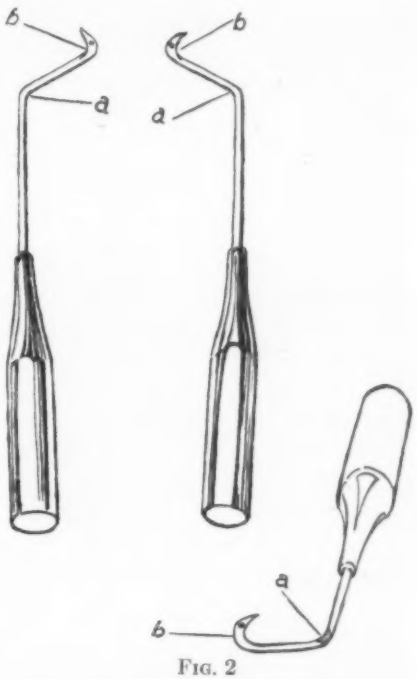

FIG. 2

Suture carrier.

Instrument at left is designed for use on the right shoulder; the one at the right, for the left shoulder.

DESCRIPTION OF SUTURE CARRIER

The instrument is seven and three-quarters inches long. The handle is heavy, and lies comfortably in the hand. At the height of seven inches, the handle forms an angle of 110 degrees. The head of the instrument is turned toward the surgeon, and forms an angle of 90 degrees with the handle (Fig. 2). It ends in a very sharp point, shaped in such a manner that up-and-down motion of this instrument enables the surgeon to drill a hole into the bone. Approximately one-quarter of an inch away from the tip of the instrument, a hole is drilled to permit the threading of a suture. The edges of this hole are smoothed down to prevent the suture from being cut as the instrument pierces the bone.

The instrument is made of tempered steel and is not flexible. It may also be used to advantage in other operative procedures requiring suturing of soft structures to bone, such as tendon transference.

NOTE: The writer wishes to thank Mr. Edmund J. Gernant, bracemaker, Orthopaedic Service, Pratt General Hospital, for his help in designing this instrument.

BLADE-PLATE FIXATION

Report of a Case

BY IRWIN A. JASLOW, M.D., SAYRE, PENNSYLVANIA

From the Section on Orthopaedic and Traumatic Surgery, Guthrie Clinic and Robert Packer Hospital, Sayre

Blade-plate fixation of intertrochanteric and subtrochanteric fractures of the femur, as well as of high femoral osteotomies, has been described by Moore and has proved its efficiency in a number of cases in the experience of the author. A second angle has been added by Blount, and this has broadened the variety of cases in which this form of internal fixation can be used. This wider use includes such conditions as the correction of coxa vara and the treatment of old ununited fractures of the femoral neck, as well as of fresh ones. In recent fractures, an abduction osteotomy is performed to convert a sheering fracture into an impacting one.

In the usual case, with a firm fixation of the blade-plate, no plaster is required postoperatively. The use of coarse-threaded screws enhances the efficiency of the fixation, as these threads grasp the cortical and cancellous bone more firmly and are less likely to be stripped under excessive strain.

In the case here reported, blade-plate fixation was performed and unusual sequelae developed. In this particular case, plaster fixation was used for the first six weeks for added protection because of the known alcoholic habits of the patient, which, incidentally, were responsible for both the first and second fractures. The case is unusual in that the refracture was obviously not through the old line of fracture, but took place under the sturdy and well-fixed blade-plate. Evidence of the firm fixation was inferred from the fact that it was possible to rebend this plate back into normal alignment. In doing this, the strain was thrown primarily upon the screws used for fixation.

FIG. 1

Comminuted fracture on admission, November 11, 1945.

CASE REPORT

A white male of sixty-six years was admitted to the Hospital on November 11, 1945, after having fallen downstairs. He was suffering from a comminuted subtrochanteric fracture of the left femur (Fig. 1). Skeletal traction was applied, and the patient was made comfortable in bed. In view of the patient's age, it was felt desirable to make him ambulatory as quickly as possible. Therefore, three days later, open reduction was performed and internal fixation was effected with a Moore blade-plate with a three-inch blade and a five-inch plate, which was fixed to the femoral shaft by seven screws. A plaster hip spica was applied and was left on for six weeks, following which the patient returned to the Hospital for removal of the plaster. While roentgenograms did not reveal bony union of the fractured femur (Fig. 2), the fixation was firm enough to allow the patient to be ambulatory on crutches. The patient returned to his home, using crutches and bearing partial weight on the left lower extremity, without untoward pain or difficulty.

Sixteen weeks after the open reduction, the patient was readmitted to the Hospital, after having fallen downstairs again on the previous evening. The patient felt some discomfort at the old fracture site, but no real pain,

FIG. 2

FIG. 3

Fig. 2: Blade-plate fixation after removal of the hip spica on January 3, 1946. Clinically the fracture is solid, but there is no roentgenographic evidence of bony union.
Fig. 3: Roentgenogram showing refracture and bent plate on February 26, 1946.

FIG. 4

FIG. 5

Fig. 4: Roentgenogram taken after manipulation; the plate shows a reverse curve and reveals that the most recent fracture (arrows) passed through what was intact cortical bone, rather than following the old fracture line. In the course of the manipulation, the middle screw has obviously been loosened.
Fig. 5: Roentgenogram taken October 30, 1946, reveals solid bony union. Apparent change in position is due to external rotation at time film was taken.

and only minimum increase in discomfort on motion of the left lower extremity. However, there was marked deformity, and roentgenograms revealed that a new fracture had taken place and that the plate had bent (Fig. 3). There was marked lateral bowing, shortening, and adduction deformity, correction of which was necessary for a good walking leg. The following morning, preparations were made to remove the plate and bend it straight, or to replace it with another plate for internal fixation. Before doing this, however, it was decided to try a closed reduction. Under pentothal anaesthesia, with the patient lying on the affected side and the pelvis held by a strong assistant, the femur was carefully and firmly manipulated, until the limb was clinically straight with no shortening and no bowing. Considerable force was used in doing this. A roentgenogram was taken at this time to confirm the fact that the plate had not been broken (Fig. 4); and, when this had been determined, the patient was discharged, without further fixation, for convalescence at home in bed. Later roentgenograms showed solid bony union with no change in the position of the fragments or of the plate (Fig. 5).

DISCUSSION

This case demonstrates the dependability of blade-plate fixation under unusual stress and strain. Coarse-threaded screws, by biting deeper into the bone, seem to offer firmer fixation than those with finer threads. It would appear advisable to use the coarse-threaded screws in almost all cases of internal fixation.

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SPINA BIFIDA APERTA AND CONGENITAL STRICTURE OF THE SPINAL CANAL*

BY PROF. DR. MÜNIR A. SARPYENER, ISTANBUL, TURKEY

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A review of the international literature indicates that, in some cases of spina bifida occulta, the laminae, which should normally meet posteriorly, curve toward the vertebral canal, causing constriction. Recently, the writer has found that the congenital stricture is not always found in the same region as the spina bifida occulta. In some cases, there have been strictures without any evidence of spina bifida. In every case of spina bifida aperta, search must be made for a stricture somewhere in the spinal canal. A recent case proves the correctness of this point of view and is worthy of publication.

CASE 1. M. T. was twenty-two years old when he first came to our Clinic. Four years before, he had been operated upon at another hospital, and a tumor as large as a new-born infant's head had been removed from the lumbosacral region. Despite the operation, there had been no improvement of the enuresis, spastic gait, or flexion of the hips from which he had been suffering. After a preliminary spinal puncture, a suboccipital injection of 40 per cent. lipiodol was given. Although most of the opaque oil stopped at the level of the first lumbar vertebra, a few drops extended down to the second. Laminectomy was performed between the

FIG. 1-A

FIG 1-B

Fig. 1-A: M. T. Roentgenogram taken after suboccipital injection. The lipiodol has stopped at the first lumbar vertebra.

Fig. 1-B: Roentgenogram taken after laminectomy of the first and second lumbar vertebrae. The lipiodol has descended to the lower part of the spinal canal.

* Edited by Leo Mayer, M.D., New York, N. Y.

first and second lumbar vertebrae. During the first twenty-four hours, the enuresis disappeared completely; and, although it recurred, it gradually diminished, and within a week had stopped. The flexion of the legs improved 60 per cent., and the spasticity, together with the pain, disappeared.

Girdle pain may also be caused by a congenital stricture of the canal, as evidenced by the following case.

Case 2. N. F., a policeman, twenty-nine years old, had suffered from intermittent girdle pain as long as he could remember. Three years previous to our seeing him, the pain had become so severe that he was unable to move his lower extremities. After some treatment and rest, he regained the use of his limbs, but the severe pain continued. He had sought advice at many hospitals and clinics, and various diagnoses had been made,—"sciatica", "rheumatism", syringomyelia, and gout. Roentgenograms were taken of the spine and lower extremities. These were negative, as was also the Wassermann reaction. His pain, which at first could be favorably influenced by rest, became worse, and did not improve even when he was in a recumbent position. Physical examination revealed only a slight limitation of motion between the third and fourth lumbar vertebrae. Despite the negative roentgenograms of the spine, a suboccipital injection of 40 per cent. lipiodol was given. In one film, taken two and one-half hours after injection, the lipiodol had stopped at the upper end of the fourth lumbar vertebra. At the time the laminectomy was performed at the level of the third and the fourth lumbar vertebrae, we saw that the lamina of the fourth vertebra had slipped in front of the third vertebra. As a result, a sharp angulation had occurred. The lamina of the fourth vertebra had become hypertrophied so as to fill most of the spinal canal. All the abnormal bone causing the stricture of the canal was removed. Within twenty-four hours after the operation, pain had diminished, and at the end of a week, the patient could move freely. After a fortnight the pain had disappeared, and he was able to walk normally.

The writer has made a number of observations which seem to indicate a causal relationship between stricture of the spinal canal (spina bifida) and certain developmental

Fig. 2-A

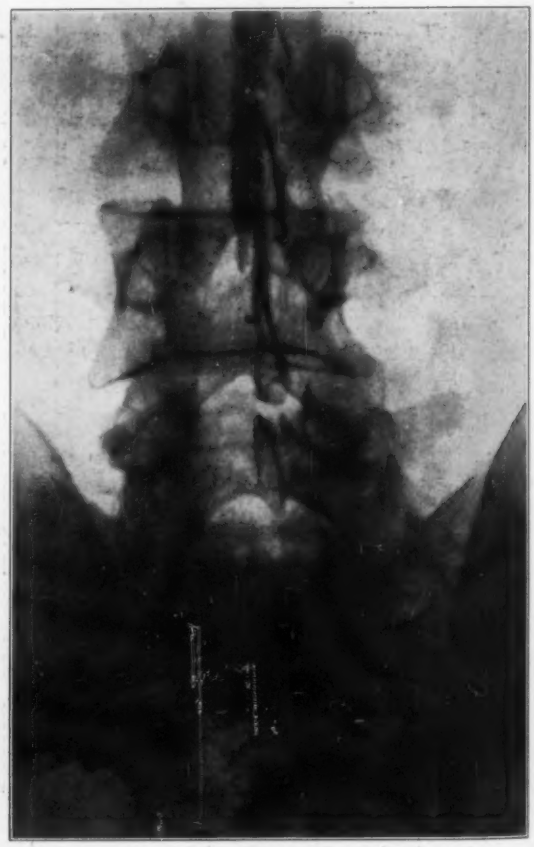

Fig. 2-B

Fig. 2-A: N. F. Roentgenogram shows spine to be apparently normal.
Fig. 2-B: Roentgenogram taken two and one-half hours after the suboccipital lipiodol injection. Lipiodol remains at the upper end of the fourth lumbar vertebra.

FIG. 2-E

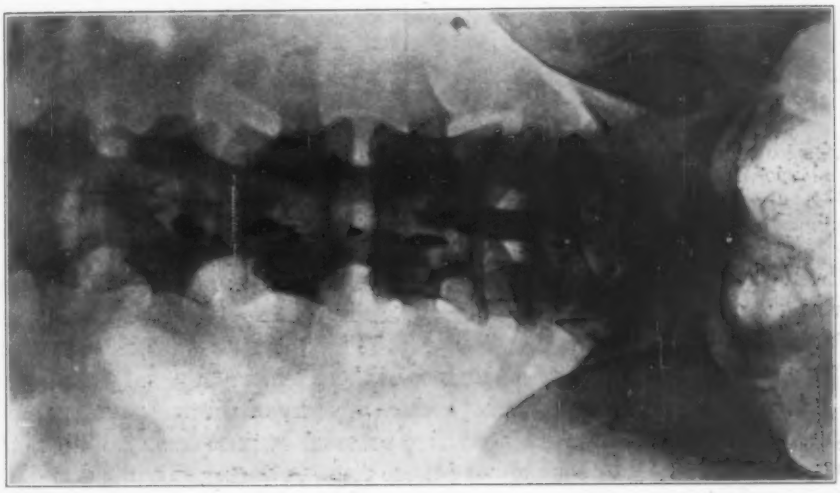

FIG. 2-D

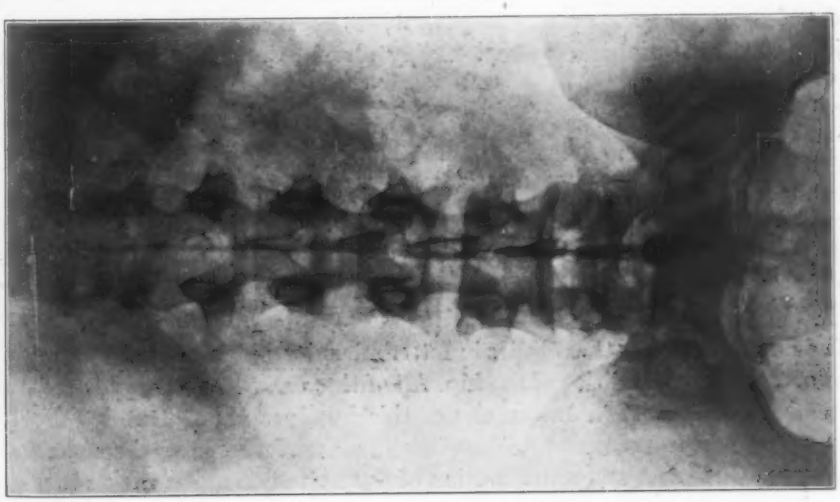

FIG. 2-C

Fig. 2-C: Roentgenogram, taken soon after that shown in Fig. 2-B, shows that the lipiodol has gone down and can be seen like a vertical line.
Fig. 2-D: Roentgenogram, taken after laminectomy, shows that the lipiodol went down without stopping until it reached the fifth lumbar vertebra.
Fig. 2-E: Roentgenogram shows that even after the operation the vertebral canal, which had been enlarged by laminectomy, remained narrow up to the fourth lumbar vertebra, without causing harm.

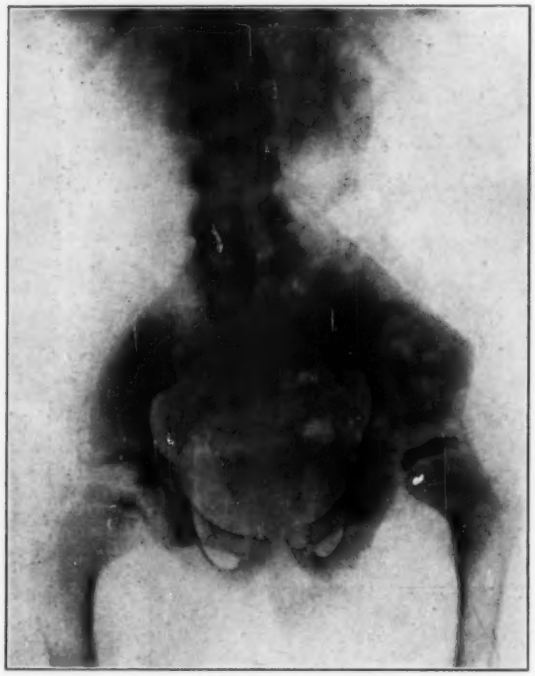

FIG. 3-A

FIG. 3-B

Fig. 3-A: M. Patient, nine years old, with Legg's disease of both hip joints. Two and one-half hours after suboccipital lipiodol injection, the lipiodol can be seen at the level of the second, third, and fourth lumbar vertebrae, showing existence of a stricture.
Fig. 3-B: Lateral roentgenogram of same patient.

conditions of the hip and knee,—such as coxa plana, coxa vara congenita, subluxation of the hip (dystrophia subluxant), malum coxae juvenilis (Legg-Calvé-Perthes disease), malum coxae senilis, and Osgood-Schlatter disease (see Fig. 3-A). Thus far, no satisfactory theory has been presented to explain the occurrence of these abnormalities. It seems to the author that, if stricture of the spinal canal can produce atrophy of the soft parts, pain, and spasticity, it could also affect the bones by exerting pressure against their trophic nerves. This theory is strengthened by the occurrence of these diseases during childhood and early adolescence. That is the time when the spinal cord is narrow. After the spinal cord widens, as it does during adolescence, the lesions tend to heal. Strong confirmation of this theory is given by a study of roentgenograms published in various books and journals, which show both the hip joint and the lumbosacral region. My observations in many cases are as follows:

	Associated with Spina Bifida	Not Associated with Spina Bifida
Legg-Calvé-Perthes disease	42	1
Dystrophia subluxant (subluxation of hip)	31	1
Malum coxae juvenilis	2	0
Malum coxae senilis	3	0
Coxa vara congenita	10	0
Osgood-Schlatter disease	6	1

At this Clinic, as well as in other clinics in Istanbul, spina bifida has been found in almost every one of these abnormalities of the hip. All of them show a dystrophic condition of the bones forming the hip joint. Incoxaplana, this involves chiefly the epiphysis of the acetabulum, which shows abnormal or delayed ossification. In congenital coxa vara, the epiphysis of the neck is affected, and a diminution of the normal angle of the neck results. In dystrophia subluxant, the acetabulum is flat; stalactite-like formations occur at its

upper margin; the head of the femur resembles the bumper of a train; the area of ossification shows fragmentation; and the neck is shorter. In malum coxae juvenilis, there is an abnormality of the ossification zone of the neck, displacement of the head, flattening of the capital epiphysis, and diminution of the angle of the neck of the femur. All of the changes indicate a widespread dystrophy, most probably caused by interference with the trophic nerves. The accompanying atrophy of the soft tissues may be partly due to inactivity, but more probably to trophic influences.

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WILLIAM BARNETT OWEN

1880–1947

William Barnett Owen died on February 23, 1947, after a short illness, at his home in Louisville, Kentucky. He was sixty-six. His death brought sorrow to his many friends, by whom he was held in high esteem, both as a man and as a surgeon.

Dr. Owen was a native of Kentucky, the son of Mr. and Mrs. Jordan Owen, with whom he moved to Louisville in 1893. He was graduated from the University of Louisville Medical School in 1903, and completed his training in orthopaedic surgery at the Hospital for the Ruptured and Crippled in New York. He began his practice in Louisville in 1906, and devoted the entire forty years of his professional life to the teaching and advancement of orthopaedic surgery and to the care of orthopaedic patients in the community.

Early in his career as an orthopaedic surgeon, Dr. Owen realized the many disadvantages attendant upon the care of the crippled child in the wards of the average general hospital. With the aid of many of his devoted friends and the cooperation of the Kosair Temple of the Shrine, he undertook the founding of a crippled children's hospital for Louisville. The Kosair Crippled Children's Hospital was opened in 1925 with Dr. Owen as Chief of Staff, a position he held until his death. Under his able direction and guidance, the Hospital developed into an institution of over one hundred beds, with the equipment and trained personnel necessary to provide for the many phases of modern orthopaedic surgery.

During the severe epidemics of poliomyelitis which have occurred throughout the country in recent years, the value of this Hospital to the community has been amply proved. It will continue as a monument to his vision and the unselfish service which characterized his life.

As Professor of Orthopaedic Surgery at the University of Louisville Medical School and Chief of the Orthopaedic Service at the Louisville General Hospital, Dr. Owen contributed much of his time to the teaching of orthopaedic surgery. He was an active member of many medical societies, including The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, and the Southern Surgical Association.

He will remain in the hearts of his family and friends as a kindly man, possessed of an abundant sense of humor, yet unswerving in his adherence to the principles of honesty and integrity which characterized his personal and professional life.

CORRECTION

Dr. Walter P. Blount participated in the symposium on Fractures of the Hip, presented at the Annual Meeting of The American Orthopaedic Association in June 1946. Through an error, his part in the discussion was omitted. It should have appeared after that of Dr. Mary Sherman, on page 358 of the April 1947 issue of *The Journal*.

DR. WALTER P. BLOUNT, MILWAUKEE, WISCONSIN: The first two speakers have demonstrated conclusively that there is an unsolved problem in the management of the complications of fracture of the neck of the femur. Non-union, which is preventable, is being eclipsed in importance by aseptic necrosis and degenerative changes. Several measures have been suggested for the prevention of these complications, but as yet there has been no satisfactory solution. We must remember that most of the patients are old and feeble. Most of them will not recover completely. Anatomical perfection is not required. The patient's opinion of the result, as well as that of the surgeon, should be considered in evaluating the treatment.

In this connection, let us look again at the roentgenogram of a high Schanz osteotomy, thirteen years after the operation and sixteen years after the fracture [Slide]. There has been progressive degenerative change with loss of the joint interval, some destruction of the head, but good position. The appearance is like that of the last case shown by Dr. Sherman. There is obviously marked restriction of motion. Clinical examination shows sufficient flexion to eliminate backache. The patient has no appreciable pain in the hip, and is happy with the result. I think that, in this case, osteotomy was preferable to primary arthrodesis, as suggested by Dr. Gill. If pain does appear in such a patient, arthrodesis by simple pin fixation is much more likely to be successful than is primary arthrodesis.

I was impressed by Dr. Gill's figures, showing success in only 60 per cent. of the patients. It should be noted that, in his cases, the hips with successful fusions had been placed in abduction. In my experience, this position is likely to give an unsightly limp, considerable fatigue, and back pain. It is my suggestion that osteotomy be performed early, and that arthrodesis be reserved for the unsuccessful case.

With osteotomy, there are various possibilities. If the patient is not too old, and if the head is alive, the chances are that bony union will occur with a satisfactory range of motion, no pain, and good stability. The likelihood of aseptic necrosis with significant degenerative changes has been diminished by the osteotomy. The shearing force has been eliminated, and adequate circulation is restored rapidly.

If degenerative changes occur in spite of the osteotomy, a good operation has been performed for the treatment of the arthrosis. The patient may go through life without the need for further treatment. If an arthrodesis or an arthroplasty becomes necessary, the local mechanical conditions have been made more favorable for a successful outcome of the palliative operation.

If we could select in advance the cases which will do poorly, we would all agree to the institution of more radical measures to improve the prognosis. A bone graft, in addition to pin fixation, influences the union favorably. According to Dr. Harris and some of the other speakers, the likelihood of degenerative change may be increased by this procedure. I advocated a high femoral osteotomy, to be performed simultaneously with the reduction and fixation. Dr. Charles Pease of Chicago does this routinely with the use of a curved blade-plate, as indicated in the slide. This is actually an osteotomy, as described by Dr. Leadbetter. As internal fixation has become perfected, the Shanz and the McMurray-Putti-Leadbetter procedures all become more alike. In the fresh case, I prefer to fix the fracture with pins, in addition to fixing the osteotomy with a blade-plate. This is to prevent gross displacement. In the treatment of established non-union, this fixation is not necessary, because the fibrous union serves to hold the head and neck in position.

If one accepts simultaneous operation as a desirable procedure in some cases, our criteria for selection should be better established. We have been asked for a statement of our present reasons for augmenting ordinary internal fixation. There is certainly no doubt about the following: (1) senility and osteoporosis, (2) delayed reduction, and (3) verticality of the fracture. I have come to regard any one of these as an indication for the performance of an immediate osteotomy.

It has been argued by some that, if the Schanz osteotomy at the level of the lesser trochanter is good, the McMurray-Putti-Leadbetter type of procedure is better, because it directly underpins the head. I cannot agree. As demonstrated previously, the angulation of the fragments in the Schanz osteotomy underpins the head without encroaching upon the hip joint. I have two primary objections to the use of the very high displaced osteotomy in the treatment of non-union. The first is the inescapable increased limitation of motion at the hip joint. The second is instability. Recently I examined three selected cases from a large series of McMurray osteotomies for ununited fracture of the neck of the femur. In each of the cases a positive Trendelenburg sign was found. If we are to accept the patient's evaluation, the operation produced satisfactory improvement. However, an unstable hip with a positive Trendelenburg sign must be translated into fatigue and disability.

When internal fixation is used, the second objection of instability is largely overcome. It is now possible to angulate the trochanter away from the ilium so that the function of the abductors is re-established. The extremely ingenious operation, suggested by Dr. James Dickson, provides excellent mechanical relations. It will certainly produce prompt bony union at the site of the fracture. The only doubt in my mind is with regard to the late results. Will the additional operative trauma predispose to aseptic necrosis?

News Notes

The United States Chapter of the **International College of Surgeons** will hold its Twelfth Assembly and Convocation at the Palmer House, Chicago, from September 28 to October 4, 1947, under the general chairmanship of Raymond W. McNealy, M.D. The program includes the presentation of scientific papers, round-table discussions, and operative clinics and demonstrations at various Chicago hospitals.

The First European Rheumatology Congress will meet in Copenhagen and in Aarhus, Denmark, from September 4 to 8, 1947. Discussions will be conducted on the Etiology and Pathogenesis of Rheumatic Fever and Rheumatoid Arthritis, on the Treatment of Rheumatoid Arthritis, on the Social Importance of the Rheumatic Diseases, and on the Bioclimatological Problems of Rheumatology. Information may be obtained from the Bureau of the Congress, 16, Rysensteensgade, Copenhagen V, Denmark.

AMERICAN SOCIETY FOR SURGERY OF THE HAND

The first meeting of the recently organized American Society for Surgery of the Hand was held in Chicago on January 24 and 25, 1947, under the presidency of Sterling Bunnell, M.D. A program consisting of moving-picture demonstrations, presentation of cases, and formal papers was presented at Thorne Hall on the Lake Shore Drive campus of Northwestern University, Friday, January 24; and a second program of formal papers was presented at the Palmer House on Saturday morning, January 25.

On Friday morning, William H. Frackelton, M.D., presented an excellent motion picture, demonstrating the surgical reconstruction of a hand with irreparable palsy of the median and ulnar nerves and a loss of the long flexor of the thumb. In this patient, operated upon at the William Beaumont General Hospital, the sublimis tendons were attached to the proximal phalanges of their respective fingers as a substitute for the paralyzed lumbricales and interossei; the thumb was brought into adduction with the aid of a tendon graft; and a graft was substituted for the injured flexor pollicis longus. The grafts were attached to their respective insertions with the aid of "pull-out" wire sutures. The prolonged operative procedure was carried out in one stage, and the final result was excellent.

Harvey S. Allen, M.D., Michael L. Mason, M.D., and Sumner L. Koch, M.D., then presented three groups of cases, illustrating the care of compound injuries of the hand, division of the nerves and tendons of the hand, and the use of tendon grafts for injuries of the flexor tendons of the fingers. These cases represented various stages in the postoperative care: Some of the patients had recently been operated upon; in others a number of months had passed; and in some sufficient time had passed to evaluate the result.

In the care of compound injuries with fractures of metacarpals and phalanges, Allen stressed the value of the "universal splint" for maintaining the "position of function", which he and Mason had worked out in Italy and found of especial value in the treatment of severe compound injuries.

On Friday afternoon a group of formal papers were presented, all of them illustrated with lantern slides. Darrel T. Shaw, M.D., and Robert L. Payne, M.D., discussed the use of pedicled flaps for repair of soft-tissue defects; Clarence A. Luckey, M.D., and Henry D. Moon, M.D., discussed post-traumatic oedema of the dorsum of the hand; Major J. William Littler demonstrated metacarpal reconstruction with the aid of bone grafts; and Merle M. Musselman, M.D., and William H. Frackelton, M.D., reported their work on ray transference for metacarpal injuries.

The last presentation was a moving-picture demonstration of "Surgery of the Hand", prepared at various naval installations under the direction of George V. Webster, M.D. The immediate closure of amputation defects with the aid of pedicled flaps and subsequent separation of the remaining portions of the fingers, the repair of burn contractures, and the use of tendon grafts, in addition to a number of other surgical procedures, were depicted with excellent color photography.

A second group of papers were presented on Saturday morning at the Palmer House. Discussions of chronic tenosynovitis of the forearm and hand by Thomas W. Stevenson, M.D., and the use of cellophane as an interposition substance by A. W. Farmer, M.D., were followed by the President's Address and by a symposium on tendon transfers. Samuel B. Fowler, M.D., discussed the extensor apparatus of the finger; Julian M. Bruner, M.D., the use of the extensor pollicis brevis to secure abduction of the little finger; Walter C. Graham, M.D., the use of the flexor sublimis to secure abduction of the index finger; and George S. Phalen, M.D., and Richard C. Miller, M.D., the use of the extensors of the forearm as a substitute for the flexors of the fingers.

The next meeting of the Society will also be held in Chicago, January 23 and 24, 1948, but it is planned that subsequent meetings will be held in different cities. The coming meeting will be open to guests, and more specific information concerning the program may be obtained from the secretary, Joseph H. Boyes, M.D., 1401 South Hope Street, Los Angeles 18, California.

HAND SURGERY

Presidential Address *

BY STERLING BUNNELL, M.D., SAN FRANCISCO, CALIFORNIA

It is a pleasure to see the American Society for Surgery of the Hand established and on its way. This Society was born from the enthusiasm of the officers of the late War, who reconstructed the hands of our wounded. It was found by many that hands could be reconstructed and that the results were good.

Why are we banded together in this Society? What is the interest that we share? It is in part the search to overcome the difficult, as a chase for the will-o'-the-wisp. We are beginning to catch up with it; we are commencing to learn how to reconstruct such an important and indispensable organ as the hand. We have found that the more we delve, the more fascinating becomes this field. It is vast and ever expanding, including as it does most of the ailments of the extremities and of all of their tissues and structures. There is plenty of room in this field for mental acrobatics, the subject being sufficiently wide to occupy a man's whole interest. In diagnosis alone, there is much to learn and much that is alluring. It is fascinating to plan and to carry out an extensive reconstruction. This involves all the mechanics of the hand and the action of the nerves and vasomotor system, bringing useful motion, sensation, and nutrition. It is the big field of surgery of the extremities in miniature, and includes all the principles of these tissues. It is the jewelry of orthopaedic surgery. There is also the human interest—the social side—for most men earn their living by their hands. How much it means to the patient to restore to him what he has lost, when that loss is the use of his hands!

Our Society is composed of men with a kindred interest, for mutual benefit; for altruism, not unionism; and to increase and disseminate knowledge of the hand in every phase of hand surgery. We should encourage men to enter this important field, and should promote research in it.

A function of this Society should be to maintain an evaluation bureau or registry to determine and tabulate all methods, and to promote those which yield the best results. Another function should be to maintain a committee to aid research workers. It could act in an advisory capacity, encouraging them in meeting problems; and also in coordinating and in preventing duplication of work. Stimulated by our common goal of advancement, we will find many other ways to further surgery of the hand.

Surgery of the hand has lagged behind in surgical progress. Surgery of the foot, which started with wrenchings and tenotomies, has gone ahead. It was not from any lack of importance that surgery of the hand lagged. The obstacle was that the repair of the hand presents an intricate, complex problem. Reconstruction of hands is now successful, as shown by the fine results achieved by the many men who did this work in the Army and elsewhere. In nine General Hospitals, to which the care of hands was assigned, many thousands of hands were treated. For the first time in any war, through the foresight of Surgeon General Norman T. Kirk, in our Army, hands were treated as an entity. This viewpoint of having hands repaired by men trained in this specialty, hand surgery, was responsible for the good results.

In the mass production of these systematized hospitals, it was demonstrated thoroughly that the hand should be treated as an entity; and it is hoped that this classification, the merits of which have been proved in this War, will be perpetuated. This applies also to organized civilian hospitals and to private practice.

The hand specialist is not a tissue specialist; his work is regional or anatomical, just as with the specialties of eye and ear, or nose and throat. His background must include the fields of the three tissue specialties—plastic surgery, neurosurgery, and orthopaedic surgery—and he must treat the region as a whole. Hand reconstruction is intricate, and it cannot be learned in a few months. It should even include rehabilitation and the social aspects.

The hand as a mechanical unit starts at the elbow, but dynamically it starts at the opposite cerebral cortex. The hand specialty is not like palmistry, which stops at the wrist, but in a broad sense it should include the whole dynamic problem which affects the use of the hand. The nerves of the brachial plexus and of the arm are mostly hand nerves; the hand is dependent directly upon them. Since the hand is in fact the important part of the arm, the object of the arm is to innervate and support the hand. As Rowley Bristow has stated: "The surgery of the upper extremity is the surgery of the hand".

The best results in our Army were not obtained by passing hand surgery from one tissue specialist to another. The best results were obtained when one man alone, dealing with the problem as a whole, attended to these three aspects. The skin covering was then applied with consideration of hand movements, of deep structures, and of future procedures that could be known only to the one responsible for the whole problem. Although hand surgery probably consists more of orthopaedic surgery than of plastic surgery or neurosurgery, the nerves should be repaired when the hand and forearm have been dissected and lie open, instead of neces-

*Presented at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 25, 1947.

sitating double surgery. The British custom of including peripheral-nerve surgery in orthopaedic surgery works well, as the neuromuscular aspect is, of course, one problem.

Some points of progress in the reconstruction of hands in the Army may be of interest. All the knowledge gained was pooled among the groups. It was found that, if hands are kept moving, they do not stiffen. New covering was found to be best when made by abdominal flaps in two procedures; or, if the area was not suitable, tube pedicles in one or two more steps were necessary. There should be no raw surface, as this increases stiffening. Free thick skin grafts sufficed for surface burns. Much bone carpentry was done, the favored graft being cancellous bone from the ilium; fixation was accomplished by pinning. Joints were moved to positions of function by elastic or spring splinting. Proximal finger joints responded well to capsulectomy and arthroplasty. Tendon grafts were used successfully when all the principles were adhered to. Many tendon transfers were used, especially for radial palsy, to establish muscle balance in claw-hand, to correct for loss of adduction or opposition of the thumb, and to substitute for any or all of the intrinsic muscles.

Repair of nerves within the hand gave good results, as did also nerve grafts of small diameter. For nerve lesions high in the arm, there was need for collaboration of treatment by one versed in hand reconstruction to keep the hand in the position of function, to keep the joints and tendons moving, and eventually to transfer tendons. Occupational therapy proved to be of far more value than physiotherapy, although the latter was needed for repair of nerve lesions. Many cases of causalgia were cured by preganglionic neurectomy; and, by the use of this procedure, other trophic conditions were improved. There were many reconstructions of digits to give prehension, and in these the importance of nerve supply and motion were recognized. Thumb posts were useful if made short and thick, and phalangization and osteotomy were also used extensively. Pollicization of a functioning index finger from the same hand, with its nerves and blood vessels intact, proved to be very successful.

Last June, I went to England to see what they were doing in hand surgery. Brigadier Furlong, of London, had previously come here for a similar purpose, and had carried back with him what we had to offer. He is now the consultant for hands in the British Army, and I hope he will succeed in making hand surgery an entity in the British Army. Quite a few men in England are interested in hand reconstruction. Excellent recovering after burns and the making of webs are done at their four plastic centers, the plastic surgeons being the ones most interested in hands. I think they have hand cases there with worse burns than we have. Cuthbert reconstructed new thumbs, even grafting a joint into one. Seddon was grafting a ring finger from the opposite hand for a thumb. Pulvertaft showed a dozen excellent results from grafting a flexor tendon plus a paratenon into a finger, using the removable-wire technique. He and Furlong are attempting to form a British society for surgery of the hand, such as ours. Among those interested are Gillies, McIndoe, Molem, Kilner, Barron, and Moore. Let us hope that they will succeed.

Meanwhile, let us make our own Society grow in its important work. I am sure that the day will come when there will be in the various nations many active reciprocating societies for surgery of the hand.

THE AMERICAN BOARD OF ORTHOPAEDIC SURGERY

Attention is called to a change in the general qualifications for eligibility to the examination of The American Board of Orthopaedic Surgery. Each candidate who applies for Part I of the examination of The American Board of Orthopaedic Surgery after January 1, 1951, must have the following general qualifications:

GENERAL QUALIFICATIONS

1. He must be a citizen of the United States or of Canada.

2. He must be a graduate of a medical school which has been approved by the Council on Medical Education and Hospitals of the American Medical Association. In the case of an applicant whose training has been received outside the United States or Canada, his credentials must be satisfactory to the Council on Medical Education and Hospitals of the American Medical Association and to the National Board of Medical Examiners; he must have been engaged in the practice of orthopaedic surgery in the United States or Canada for at least three years prior to submission of his application.

3. He must have served an internship of twelve months in a general hospital, acceptable to the Board.

4. *He must have spent a year on an approved surgical residency, subsequent to the completion of his internship.*

NOTE: This change consists of an additional required year of surgical training before the applicant enters on special work in orthopaedic surgery.

No individual may apply for Part I of the examination of The American Board of Orthopaedic Surgery who has not completed at least one year in special orthopaedic training, in addition to meeting the general requirements.

The American Board of Orthopaedic Surgery will hold its next examination—Part II—in Chicago, Illinois, on January 22 and 23, 1948. The deadline for receipt of completed formal application and application fee is September 15, 1947. Letters of request and applications received after this date cannot be accepted.

Applications for Part II of the examination, as well as correspondence related to the special qualifications to fulfill the requirements for both Part I and Part II of the examination, should be sent to the Secretary of The American Board of Orthopaedic Surgery, Dr. Francis M. McKeever, 1136 West 6th Street, Los Angeles 14, California.

PATHOLOGICAL DIAGNOSTIC SERVICE

The American Academy of Orthopaedic Surgeons by yearly appropriation finances the Registry of Orthopaedic Pathology, a constituent member of the American Registry of Pathology. The Registry is in operation at the Army Medical Museum at present.

The Registry offers full, prompt diagnostic service by skilled men who are particularly interested in skeletal pathology on all lesions of bones, joints, and muscles, including tumors. It also holds cases in its files for follow-up in a very efficient manner.

As this is a nation-wide repository, great quantities of pathological material will accumulate for study and research. Individual cases, however, will be reserved for the referring surgeon, unless permission is given to release the material for general use.

Prepared specimens, gross or microscopic, should be sent by local pathologist or laboratory to: Registry of Orthopaedic Pathology, Army Medical Museum, 7th Street and Independence Avenue, S.W., Washington 25, D. C. If possible, an abstract of the case history and the roentgenograms should accompany the slides or tissue. Quick diagnosis is afforded if properly prepared material is sent.

Surgeons are urged to avail themselves of this advantage offered by the Academy. There is no charge for this service.

Robert W. Johnson, Jr., M.D.
Chairman of the Committee

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Spring Meeting of The British Orthopaedic Association was held at University College, Exeter, and the Princess Elizabeth Orthopaedic Hospital, on April 25 and 26, under the presidency of Mr. George Perkins, M.C.

A symposium on "Surgical Treatment of Tuberculosis of Bones and Joints" was opened by Mr. G. R. Girdlestone, who stressed the importance of strict criteria in the estimation of the results of treatment, and remarked upon the rarity of dissemination of the disease by operation, if the operation is well timed, and preceded and followed by immobilization. He condemned concern with the local lesion to the exclusion of the treatment of the tuberculous patient as a whole, and emphasized the importance of prolonged care after discharge from the hospital. He attached much importance to serial estimations of the erythrocyte sedimentation rate in assessing progress.

Mr. Norman Capener gave a valuable and comprehensive review of tuberculous disease of the spine in 351 patients, emphasizing the differences in the disease and its response to treatment in children and adults. In the first fifteen years, involvement of the lower thoracic (dorsal) area predominated; afterwards the lumbar region was more commonly affected. Of the series reported, 177 patients were treated by arthrodesis, with no mortality within the first nine months. The tibia, which provided the graft, was fractured only once, in contrast with the experience in traumatic cases. Mr. Capener thought that the key to the treatment of thoracic spinal disease might be treatment of the abscess.

Mr. M. C. Wilkinson, speaking of tuberculous disease of the hip, stated that he had found an unstable hip in twenty-two out of fifty patients, treated only conservatively. The value of the operative treatment was measured by its success in securing stability and in safeguarding against recurrence. In seventy-five cases, Mr. Wilkinson's operative mortality was two deaths early and two later. He had used osteotomy, with medial displacement of the distal fragment, but lately he had supplemented this with an extra-articular femoral graft, slid along the upper border of the neck. Operation was performed in the presence of active disease after the patient's resistance had been raised by conservative treatment; and the re-ossification which ensued might be ascribed, perhaps, to auto-inoculation or to the decompression of tuberculous foci. Mr. Wilkinson said that bony ankylosis might take as long as two years, although the hip usually became quite stable before that time. Many roentgenograms of patients so treated were shown. Mr. Wilkinson's view that displacement osteotomy was often of great value in the treatment of tuberculous hip joints was supported by Mr. D. Wainwright, who showed how a combination of osteotomy and an ischiofemoral graft produced rapid bony ankylosis. Mr. Wainwright showed also the result of supplementing long oblique osteotomy by traction, so that not only was apparent lengthening produced by angulation, but also real lengthening by distraction. Dr. J. Delchef advocated early arthrodesis, while the disease was still active. Mr. H. A. Brittain

considered that the hip demanded a different treatment from the other joints of the lower limb, because it could be short-circuited from weight-bearing by ischiofemoral arthrodesis.

Mr. J. P. Campbell reviewed eighty-nine cases of tuberculosis of the knee treated at Harlow Wood Orthopaedic Hospital, and found a quarter of the cases to be purely synovial in type. In some patients with osseous lesions, a serviceable range of movement developed. Intra-articular arthrodesis resulted in bony fusion much more quickly in cases of more than three years' standing than in more recent cases similarly treated. Bone-grafting operations were reserved for adults, in whom they supplemented intra-articular arthrodesis or were used to promote bony fusion where resection of the joint alone had failed. Dr. J. Mortens, reviewing seventy-six cases, concluded that arthrodesis should be postponed to the age of thirteen or fourteen, if an epiphysis were involved, but that, otherwise, nine years was not too young an age for the operation.

In considering 118 cases of tuberculosis of the foot and ankle, Mr. B. L. McFarland contrasted the very good, though slow, response to conservative treatment in children with the frequently poor result in adults, in whom dissemination or sinus formation frequently made amputation necessary; conservative treatment, with or without arthrodesis, might be indicated in some younger adults, but in the older patient with tuberculosis of ankle or tarsus, amputation was not merely justifiable, but often imperative.

Mr. J. A. Cholmeley reviewed ninety-four of one hundred cases of tuberculosis of bones and joints of the upper limb, treated in the Royal National Orthopaedic Hospital (Country Branch) in the years 1924 to 1946. The parts affected were: shoulder in thirty-six cases, elbow in twenty-five, wrist in twenty-two, metacarpals and phalanges in ten, and humeral shaft (local lesion) in one. All patients received conservative treatment, supplemented in a few by operation,—arthrodesis of eight shoulders in adults, excision of an elbow, and partial excision of another elbow with drainage for secondary infection, and local excision of the local humeral lesion. Arthrodesis of the shoulder, which was often determined by occupation, gave good results in adults, with bony fusion in every case, whereas recurrence took place in three of the shoulders not operated upon. In two elbows, including the one excised, there was recurrence; there was none in the wrist, metacarpal, phalangeal, or humeral cases.

Sir Reginald Watson-Jones concluded that tuberculosis of bones and joints presented, from the viewpoint of treatment, two diseases,—one in children and one in adults. Both demanded conservative treatment; in children this usually sufficed, but in adults it should often be supplemented by surgical fusion after quiescence of the disease. He considered that the position was reversed in the case of the spine, which should be more often arthrodesed in children and more rarely in adults, because, in children, conservative treatment of thoracic disease left an unstable spine with increasing deformity; whereas, in adults, the disease in the lumbar area nearly always led to spontaneous ankylosis.

Dr. M. N. Smith-Petersen gave an extremely lucid account of his operation of cup arthroplasty of the hip, illustrated by slides and films. The restoration of shapely, smooth, cartilaginous articular surfaces was demonstrated convincingly.

Mr. W. Alexander Law had found that some 80 per cent. of Dr. Smith-Petersen's cup-arthroplasty operations gave a result satisfying to patient and surgeon, but it was essential that the former should co-operate actively with exercises for two years.

Mr. H. G. S. Korvin concluded, from roentgenographic evidence, that the pathological changes in pseudocoxalgia were those of ordinary aseptic necrosis, and that destructive changes were the biological consequences of the mechanical damage of weight-bearing.

Mr. F. C. Durbin had followed up 525 cases of sciatica and selected 147 cases of sciatica, with neurological signs, treated without operation. Of 123 patients to whom plaster jackets were applied, seventy-nine were relieved or cured.

Mr. G. Blundell Jones had investigated the penicillin content of the synovial fluid of knees with open war wounds, forty-eight hours after a single instillation of 100,000 units. He found retention, in adequate concentration, provided the effusion was not diminishing. Absorption of effusion led to more rapid disappearance of intra-articular penicillin; but, at this stage, penicillin was no longer needed in the joint. Penicillin, given intramuscularly, was not found in adequate concentration in the synovial fluid of the joint, if the joint were completely immobilized.

Mr. A. L. Eyre-Brook showed a patient with bilateral cineplastic forearm stumps and two patients with Krukenberg forearm stumps. The success of the operations (performed by German surgeons) was undoubted, and function appeared particularly good in the Krukenberg stumps on account of the preservation of sensation.

Clinical cases were demonstrated at the Princess Elizabeth Orthopaedic Hospital by its staff and that of the Mount Gold Orthopaedic Hospital, Plymouth. Mr. Norman Capener showed cases of lateral rachiotomy for Pott's paraplegia and his own modification of Neufeld nail-plate fixation of pertrochanteric fractures. Mr. G. J. Lillie showed cases of osteoclastoma and enchondroma, treated by radical excision and grafting. Mr. F. C. Durbin presented examples of arthrodesis of the shoulder, showing short "tri-fin"-nail fixation, and of the elbow, showing the value of excision of the radial head. Mr. G. Blundell Jones showed cases of osteomyelitis of the calcaneus (os calcis) treated by Gaenslen's "cloven-hoof" operation. He presented also cases of osteomyelitis of the femur, discussing penicillin treatment and the need for adequate

surgery in such cases. Mr. M. H. Salz showed some cases of synovectomy of the knee joint, and Mr. A. E. Jowett demonstrated arthrograms of this joint with opaque media.

At the business meeting, the following elections were made:

Honorary Fellow:

M. N. Smith-Petersen, M.D., Boston, Massachusetts

Fellows:

F. P. Fitzgerald, F.R.C.S., London
R. D. McKellar Hall, F.R.C.S., Perth, West Australia
H. I. Maister, F.R.C.S., Cape Town, South Africa
S. M. Milner, F.R.C.S., Manchester
S. B. Morris, F.R.C.S., Auckland, New Zealand

Associate Members:

E. W. O. Adkins, F.R.C.S., Stanton-by-Bridge
Ross Bloom, F.R.C.S., London
J. F. Bourdillon, F.R.C.S., Oxford
J. Tulloch Brown, F.R.C.S.E., Motherwell, Lanarkshire, Scotland
A. F. Bryson, F.R.C.S., Loughton
J. E. C. Cherry, M.D., F.R.C.S.I., Dublin
P. N. Cutner, F.R.C.S.E., London
F. W. T. Davies, F.R.C.S.E., Porthcawl, South Wales
T. Denness, F.R.C.S., Delhi, India
T. J. Fairbank, F.R.C.S., Reading
P. A. M. Fitzgerald, M.D., M.Ch., Dublin
G. C. Gordon, F.R.C.S.E., Sheffield
Stewart H. Harrison, F.R.C.S., Birmingham
C. Hollenberg, M.D., M.Ch., London
R. A. King, F.R.C.S., London
Norman S. Martin, M.D., F.R.C.S., London
J. S. Maxwell, F.R.C.S.E., Edinburgh
G. Osborne, F.R.C.S.E., Southport
Marion A. Pearson, F.R.C.S.E., Glasgow
C. C. Slack, F.R.C.S.E., Southport
D. F. Thomas, F.R.C.S., Scunthorpe
F. R. Tucker, M.D., M.Ch., F.R.C.S.E., Southport
R. F. Winckworth, F.R.C.S., Taunton

Surgical Appliances Research Fellowship:

John Gull

It was announced that the 1947 Annual Meeting would be held in Manchester on October 24 and 25.

THE INTERNATIONAL SOCIETY OF ORTHOPAEDIC SURGERY AND TRAUMATOLOGY

The first meeting of the Society since the War was held in Brussels on October 3 and 4, 1946. Representing the United States at this meeting was Dr. H. W. Meyerding of Rochester, Minnesota, and at a general meeting it was voted that he should preside at the next Congress, which will be held in Amsterdam in September 1948. Three new countries were admitted to membership in the Society,—Iceland, Mexico, and Turkey. It was decided to increase from forty to sixty the maximum number of members in the Society from any one country.

One of the most interesting sessions of the meeting was devoted to multiple-stage operations and to other methods for the functional improvement of patients after amputation. It was agreed that the most important factors to be considered are suitable treatment of the stump so that it will be more useful and so that it can be easily adapted to a prosthesis; how to deal with the painful stump; and how best to educate the patient to control his prosthesis.

The leading report on multiple-stage operations was given by Mr. George Perkins of London. He mentioned the advantages of the Krukenberg operation for patients who are blind, or who live far from a center where a prosthesis may be renewed or repaired. This operation produces an unsightly stump, by splitting the forearm into two prongs, but it thus renders a prosthesis unnecessary. The patient retains tactile sensation. In Berlin this technique was followed on 600 patients who had lost both arms, and, as a rule, it was done

only on one side. The operation is of prime concern to the plastic surgeon, because a great deal depends upon the shaping of the flaps and upon the proper covering of the excess raw area with transplanted skin.

Pain in the stump can result from an ill-fitting socket, an irritated neuroma, or from widespread hyperaesthesia of the skin. Of course, the ill-fitting socket can best be remedied by the person who fits the prosthesis. Pain caused by an irritated neuroma is the result of repeated traction from adhesions lying between the neuroma and the muscles or between the neuroma and the skin. To prevent such adhesions, a careful suture of the deep fascia should always be made; or, if the adhesions are between the neuroma and the muscles, the muscles should be made to contract voluntarily within a few days of the amputation.

Mr. Perkins also pointed out that it is not enough to excise a painful neuroma; it is preferable to leave it undisturbed and to excise a portion of the main trunk higher up, at a site where it can be approached through virgin tissue, and where the new neuroma will not be pressed upon by the prosthesis.

As for the treatment of hyperaesthesia of the skin, it presents a difficult problem to the surgeon, since the underlying cause is obscure. The condition is not cured by the excision of portions of all of the main trunks; nor does chordotomy relieve the symptoms, as a general rule.

The cineplastic operation was advocated as one which gives the patient additional sources of power. In an amputation above the elbow, one scapula can be used to control the elbow, the other to rotate the forearm, and the triceps and biceps are used to open and to close the fingers. The cineplastic operation should not be performed unless the muscles to be used have an effective range of shortening. They should be free of scar tissue, and trained by active exercises before the operation.

In the discussion which followed the report by Mr. Perkins, many of the world's foremost orthopaedic surgeons took part.

Dr. Annovazzi, of Milan, gave results of 500 amputations, which had been performed as a consequence of industrial accidents. From his experience, he would advise against the complete primary suture, except in cases where tissues are healthy, and even then, according to the dictum of Putti, drainage should be instituted. Whenever there is the slightest doubt as to the viability of tissue, a secondary suture is recommended.

Dr. Bastos Ansart, of Madrid, presented interesting conclusions from cineplastic operations:

1. Bilateral upper-limb amputees should be provided with a double skin tunnel (Sauerbruch). The extension tunnel is used to obtain flexion of the fingers; the flexion tunnel, to produce flexion at the wrist.

2. When only one arm has been amputated, a cineplastic operation with the formation of a skin tunnel may be tried.

3. Bilateral forearm amputees should be provided with Krukenberg stumps.

4. The Pellegrini tunnelization should be used only in exceptional cases.

5. A patient who has lost his thumb can be given another at the cost of his first metacarpal bone.

Dr. Delchef, Director of the *Neerysche Clinique* in Brussels, and Dr. Van Cauwenberghe showed a patient who had had amputations of both forearms; the Krukenberg operation had been done on the left side on July 23, 1946, and the Pellegrini cinetization on the right on August 17, 1946. The patient was already using his Krukenberg stump and his temporary prosthesis.

Dr. P. G. K. Bentzon, of Copenhagen, Editor of *Acta Orthopaedica Scandinavica*, showed a film on professional readaptation of amputees in the Scandinavian countries.

Professor F. Delitala, of Venice, director of *Chirurgia degli Organi di Movimento*, showed a slight modification of the Krukenberg procedure, in which very short prongs, not longer than the terminal phalanx of the thumb, were left. These do not alter the shape of the stump, and have been found to have considerable strength. Bilateral amputees could be supplied with a phalangization (Putti) on one side, and a shorter digitation on the other for more delicate work.

Professor O. Scaglietti, director of *Bibliografia Ortopedica*, gave the results of his experience at the *Istituto Rizzoli* in Bologna, where 3,844 patients have been examined during the five years of the War, and 1,981 operations have been performed.

Professor Marcel Fèvre, of *l'Hôpital Saint-Louis*, Paris, gave his impressions of the Krukenberg operation as he saw it performed in Austria, at a center for amputees of the German Army at Feldkirch.

Dr. Hendrix and Dr. Kempeneers, of the Orthopaedic Institute and Prosthesis Section of *l'Hôpital St. Pierre* in Brussels, stated their belief that the head of the fibula, or a fibula which is too long, is often a cause of pain when the prosthesis is applied. In such cases, removal of the fibula is indicated, and may be done through a posterolateral incision. Later the delegates to the Congress visited operative sessions at their Clinic, which were presided over by Dr. Robert Soeur.

Dr. Marino Zuco, of Rome, presented a film showing recent developments in prostheses.

Dr. Christian Rocher, of the *Faculté de Médecine* of Bordeaux, spoke of multiple-stage operations on young amputees, which are required by the unequal growth of the skeleton and the soft tissues. He covers a wound, caused by the excision of a terminal scar of a femoral stump, by taking a skin flap from the lateral part of the stump and turning it upside down, using it as a pedicle graft. Stumps which require this procedure should be straightened, as they cannot otherwise be fitted properly with prostheses.

Dr. Scholder, of Lausanne, Switzerland, stated that the importance of lateral swinging of the trunk depends upon muscle atrophy and upon the way the prosthesis fits the stump. In the case of amputation of

the femur, it is inversely proportional to the length of the stump. Lateral swinging of the trunk aims at two effects: to make sure that the pelvis is kept straight in proper relation to the prosthesis, and to make up eventually for the lack of static equilibrium of the apparatus. To avoid swinging, the stress on the stump should be in the same line as the stress on the foot.

Dr. Sven Kiaer, of Copenhagen, reported that in 1,083 amputations made in the orthopaedic hospital in that city during the years 1936 to 1945, there were found only twenty-six cases of painful stumps. Treatment should be started early, and according to the peripheral or to the central origin of the pain, an operation should be performed on the irritating focus or on the chorda or on the brain cortex.

Dr. Van Assen, of Rotterdam, described re-making of the arch of the foot after excision of the big toe and of the first metatarsal bone. He divides the base of the second metatarsal bone, and fixes the distal fragment to the first cuneiform.

Professor Sandro Marconi, of the *Ospedale Umberto e Istituto dei Rachitici*, Brescia, prefers an amputation through the metatarsal bones to the Sharp, Lisfranc, or Pirogoff methods. He considers the Gritti amputation preferable to amputation at the lower third of the leg. For the upper limb he recommended the Krukenberg operation.

Part of the meeting was given over to the presentation of special reports. Dr. Merle d'Aubigne, of the *Hôpitaux de Paris*, spoke of operations on those wounded in the War, which he had performed in the *Centre National de Chirurgie Réparatrice de Paris*. He pointed out that with cancellous bone it is possible to rebuild a bone extremity, and to obtain mobility in the new joint. In regard to the shoulder, he feels that it is better to aim for ankylosis; while in the elbow joint, it is possible to replace the trochlea of the humerus by a bone fragment cut from the iliac wing. In the knee joint, the destruction of one of the condyles may be repaired, using the patella as a pedicle graft and completing it by grafts of cancellous bone.

Dr. Maurice Guilleminet, of Lyon, told of three cases in which he restored functional opposition of the thumb by transplantation of the flexor pollicis longus, and the local adaptation of the method of medullar pinning of the long bones.

Dr. Meyerding, of Rochester, Minnesota, presented a report on the surgical treatment of primary malignant tumors of bone, which include osteogenic sarcoma, fibrosarcoma, Ewing's sarcoma (hemangio-endothelioma), multiple myeloma, and primary giant-cell sarcoma of bone. He stated that surgical treatment is the best method in such conditions, as it permits biopsy, with gross and microscopic study of tissue, which are valuable aids in diagnosis. The surgical treatment depends upon the location of the growth, the extent of the lesions, and the grade of degree of malignancy, all of which are important factors to be taken into consideration. Routine roentgenographic examination of the thorax should be performed, in order to exclude recognizable metastasis to the lungs. Although efficient laboratory facilities permit early diagnosis, it will be impossible to give to the patient who has a primary malignant tumor of bone an improved prognosis, until all general practitioners carry out routine roentgenographic examination of all painful areas.

In cases of osteogenic sarcoma, of the patients treated surgically, Dr. Meyerding found that 23.4 per cent. lived five or more years; whereas, of those treated by non-surgical methods, no patient survived for five years. In cases of fibrosarcoma, of the twenty patients traced, eight, or 40 per cent., survived for five or more years. Early amputation in these cases of fibrosarcoma, arising from or involving bone, offers the best prognosis. In Ewing's sarcoma (malignant hemangio-endothelioma), the lesion is often confused with inflammatory lesions, especially osteomyelitis. There has been a trend toward radiotherapy of this lesion, after which the tumor may disappear entirely. Dr. Meyerding believes that biopsy and surgical operation are necessary and justifiable in the attempt to clarify a diagnosis. Practically 88 per cent. of his patients had microscopic verification of the clinical and roentgenographic diagnosis of malignant hemangio-endothelioma; of thirty-three patients who had amputations and were traced, eight, or 24.2 per cent., were living five or more years later. Of twelve patients who underwent excision and were traced, two, or 16.7 per cent., were living five or more years later. The value of irradiation therapy is demonstrated by the fact that, of forty-seven patients who were treated by this method and later were traced, eleven, or 23.4 per cent., lived for five or more years. Seven patients who had not received treatment were traced, and were found to have died within five years.

Multiple myelomata are classified among the primary malignant tumors of bone, but are considered more as manifestations of disease of the lymphoid system than as manifestations of bone disease.

Mr. H. Platt, of Manchester, discussed giant-cell tumors of the long and flat bones. He emphasized the fact that tumors must not be confused with bone cysts; they are epiphyseal and not metaphyseal lesions. Stress should be placed on the aggressive character of the tumor for this determines the treatment, which is mainly surgical; roentgenotherapy should be reserved for non-operable tumors. Giant-cell malignant tumors are extremely rare. Mr. Platt stated that he had seen only four, and one of these belonged to the xanthoma type. None of the four patients lived more than a year after operation.

Dr. E.-H. La Chapelle, of Amsterdam, presented his studies of hunger dystrophy of bone, first described in 1919 by Viennese clinicians. Before that time, the disease had been called "rheumatism", "arthritis deformans", "neuralgia", "myalgia", "neurasthenia", or "hysteria". The patients complain of backache and pain in the legs, increased by walking, and they have a waddling gait. They hoist themselves up by

their hands when ascending the stairs. Roentgenograms show only a slight degree of decalcification and of periosteitis of the pelvis, a small bone crack here or there corresponding to an area of alteration of the bone. Similar changes may be seen in rickets and osteomalacia. Dr. La Chapelle thinks that this type of bone dystrophy should be considered as the initial stage of osteomalacia. In all such cases, the patients had been on a restricted low-calorie diet during a considerable time. All showed a lowering of the serum albumin.

Very similar to this hunger dystrophy is the syndrome described by Milkman in 1930: a patient with a considerable number of areas showing alterations of bone or cracks. Milkman mentioned that his patient had put herself on a reducing diet and lived on orange juice. It is queer that these cracks should be situated exactly on the spots where fatigue fractures generally occur, which proves that the seat of the cracks is determined by a mechanical factor.

Professor Etienne Sorrel, of Paris, one of the scientific directors of the *Revue d'Orthopédie*, professed his belief that penicillin is of great help in the treatment of osteomyelitis.

Dr. Lopez-Trigo, of Valencia, spoke of a new technique of reduction of supracondylar fractures of the humerus.

Dr. Robert Soeur, of Brussels, presented a study of the results of medullary pinning in ninety-nine patients. He stated that the operation gave very satisfactory results in closed fractures of the shafts of the long bones; that it is not recommended in compound fractures; and that it is applicable to a few fractures of the epiphysis,—such as fractures of the surgical neck of the humerus or pertrochanteric fractures.

Dr. Kopits, of Budapest, gave a practical method of joint measurement.

Mr. H. J. Seddon, of the Wingfield-Morris Orthopaedic Hospital, Oxford, showed a valuable film in which the joint movements of the foot, the knee, and the upper limb could be seen.

Mr. B. H. Burns, of London, spoke of diagnosis and treatment of herniation of the intervertebral disc.

Sir Reginald Watson-Jones, of London, presented a review of 1,000 cases of fracture of the spine, giving the various types of fractures and their treatment.

Dr. Pasquali, of Bologna, told of the "fork apparatus" which he had used to reduce thirty-nine spine fractures. By this apparatus, longitudinal traction is exerted on the fracture as well as on the articular process in cases of dislocation. In cases of angulation, the normal axis is restored.

Dr. Scaglietti, of Bologna, gave the results of early treatment by abduction in congenital dislocation of the hip. The hereditary character and geographical distribution of the deformity were considered.

Dr. M. Jaros, of Prague, stated that studies of congenital dislocation of the hip in uniovular twins make it possible to conclude that the cause of the deformity must be sought in the chromosomes. External mechanical factors would be of only secondary importance. Dysplasia of the hip looks very much like a delay in development; it is not caused by roentgenotherapy on the mother, by the overuse of spirits or tobacco, or by infection. This condition might originate in the lack of mixing of populations in some areas of Europe.

Professor Zahradníček, of Prague, spoke of the etiology of coxa plana, and showed a new apparatus for the treatment of congenital dislocation of the hip. The report was followed by a motion picture on the operative reduction of congenital dislocation of the hip.

Dr. Gruca, of Lwów, Poland, stated that since 1933 he had performed a resection osteotomy of the hip in all cases, whereas formerly he had performed arthrodesis. He performs the same operation in all cases where mobility of the joint is an absolute requirement, in bilateral coxalgia, and in tuberculous arthritis of the hip and of the knee on the same or on the other side. Where coxalgia is combined with lumbar spondylitis, he feels that the operation is indicated. Treatment is reduced to half its usual length, the cure is more radical than that following arthrodesis, and the joint remains stable and almost normally mobile. Dr. Gruca has treated ninety cases with suecessful results in 90 per cent.

Dr. Delahaye, of the *Hôpital Maritime de Berck*, stated that he had had the opportunity of treating a sixteen-year-old boy, suffering from tubereulosis of the right hip, osteo-arthritis of the lumbar spine, and tuberculous osteo-arthritis of the mid-portion of the right foot. The patient was first seen when the lesions had reached a chronic stage. The "varus-adductus" deformity of the foot has been corrected by a cuneiform dorsal arthroplasty; the ten-centimeter shortening of the right femur was treated by the subperiosteal resection of the left shaft of the femur. The Pott's disease healed spontaneously, and pseudarthrosis of the hip joint allowed a fair amount of mobility, while stability is very satisfactory. Anatomical and functional results were considered perfect.

Dr. J.-Ed. Samson, of Montreal, Canada, pointed out that he had performed arthroplasty on the knee more than 100 times, and he gave instances of a few technical details of the operation, and of the importance of early mobilization. Arthroplasty of both knees is contra-indicated, and in any case, should not be done before the patient is twenty years old. Performed under favorable conditions, arthroplasty of the knee gives perfect stability, satisfactory mobility, and a painless joint.

At the 1948 meeting, which will be held in Amsterdam, the following questions will be studied:

1. Treatment of arthritis deformans of the hip.

With reports from Belgium, France, Netherlands, Poland, Sweden, and Czechoslovakia.

2. Closed trauma of the spine.

With speakers from Austria, Spain, United States, Great Britain, and Italy.

Current Literature

DIE VERLETZTE HAND. ERKENNUNG, BEHANDLUNG UND BEHANDLUNGSERGEBNISSE DER FINGER- UND HANDVERLETZUNGEN UND INFEKTIONEN (The Injured Hand). Dozent Dr. Karl Krömer. Wien, Wilhelm Maudrich, 1945. $4.00.

In the Preface of this 300-page volume on the injured hand, the author's preceptor, Lorenz Böhler, stresses the frequency of hand injuries in industry (from 40 to 50 per cent. of the injuries in industry in various countries) and the fact that, in past years, approximately one third of the compensable expense for hand and finger injuries was incurred because of infection and loss of movement (contractures and fixation). Böhler suggests that immediate and skillful surgical treatment of the injured hand is the essential factor in preventing these complications and in securing a successful result.

Böhler states that he employs no chemical agents and no sera, except tetanus serum, and has no medico-mechanical or physiotherapy department. He recommends to others that, for the field of industrial surgery, they lock up the bacteriological, serological, and chemical laboratories and the medicomechanical and physiotherapy institutes, as they are constituted at present, because they only distract attention from what is essential.

Krömer divides his thesis into four parts. The first half of the volume is devoted to the diagnosis, treatment, and results of treatment of recent (*frische*) compound injuries of the hand; the second half to the treatment and results of treatment of infected injuries and of acute infections of the hand; to the diagnosis, treatment, and results of treatment of recent closed injuries; and to war injuries of the hand.

In the first half of the volume, devoted to recent injuries, the author details clearly his conception of the proper immediate treatment of open wounds,—careful cleansing, wound excision, and repair. Every worker in this field would commend the clear-cut principles he has outlined; and the splendid results he has secured speak both for the correctness of the principles laid down and for the manner in which they have been carried out.

Krömer advises cleansing of the field about the wound, but to the wound itself he applies iodine or a dye antiseptic to facilitate wound excision. Conduction anaesthesia is used for the field of operation. Wounds are classified into those which involve covering skin; those with opening of the tendon sheaths; those with tendon injury; those with tendon division; those with injury and division of nerves; those with division of large blood vessels; those with compound fractures of phalanges and metacarpals; and those with compound joint injuries, defects of the skin, and burns. Brief sections on foreign bodies in the hand and on injuries from indelible pencils are also included.

One gains the impression that, in spite of the very serious injuries of the soft parts which are illustrated, the majority of the 1,373 wounds were not severe, for, in the section on Nature of Injuries, the author lists only six with division of superficial flexor tendons, five with division of deep tendons, nineteen with division of both flexors, and twenty-seven with division of extensor tendons. In other words, only fifty-seven of 1,373 wounds of hand and fingers resulted in division of the flexor or extensor tendons. No mention is made in this tabulation of nerve injuries; and the question of nerve injuries is dismissed with a few brief paragraphs and the statement that the results of nerve injuries will be considered in a study to be reported in the future.

The treatment of skin defects with Reverdin grafts and the treatment of burns of the hand with tannic acid and ointments offer a sharp contrast with the skillful treatment accorded wounds of the soft parts in the earlier sections of the volume. A case illustrated by Figure 300, for example, with an extensive loss of covering tissue of the dorsum of hand and fingers, simply "cries out" for a large graft of part-thickness skin, but the reader is left to guess what was done and what result was obtained.

An elaborate statistical summary of forty-five pages follows the detailed discussion of various types of open wounds, and even includes statistics as to the duration of compensation payments made to injured patients. In the second of these tables the author states that, of 1,373 fresh wounds, 1,352 healed without local inflammatory symptoms, eighteen with local inflammatory symptoms, and three with progressive inflammatory symptoms. These statistics, and the fact that only 34.5 per cent. of the 1,136 patients required operative treatment, also convey the impression that the injuries in many of the cases listed would have to be classified as minor.

The section on infected wounds and acute infections of the hand is disappointing. It is rather a summary of the contributions of others than a clear-cut presentation of demonstrated principles and helpful directions as to treatment.

The section on closed injuries of the bones and joints is well illustrated, and demonstrates the excellent results the author has obtained by immediate reduction of complicated fractures and well-designed splinting. Plaster-of-Paris has been used almost exclusively, with the addition of Kirschner wires or fingernail extension in occasional cases.

For every surgeon interested in the immediate care of open wounds, this volume will prove stimulating and helpful. The results which the author has obtained in such cases are admirable and well worth striving to emulate.

THE INTERNAL FIXATION OF FRACTURES. Charles Scott Venable, M.D., F.A.C.S., and Walter Goodloe Stuck, M.D., M.S. (Orth. Surg.), F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1947. $5.50.

In their Preface, the authors state as the purpose of this work, "to give a factual account of the internal fixation of fractures with emphasis on the causes of past failures and the criteria for future successes".

The presentation of the early history of metal appliances in the treatment of fractures represents an amount of research, and the bibliographies accompanying this and other chapters are a valuable part of the book.

The experimental studies of the use of metals in surgery, as carried out in different countries, have been reviewed carefully.

Clinical observations by different surgeons in various countries have been followed with interest by these authors, whose names for more than a decade have been associated with the study of electrolytic reactions of various metals and alloys to the body fluids. They believe that "a clear understanding of the part which electrolysis plays in corrosion of metals in the body provides an explanation of many of the previous failures".

Reaffirming their belief that conservative closed treatment of most fractures will result in good functional union, they point out that there are very definite indications for the use of internal fixation in fracture treatment, and quote Kennedy's classification of such indications. The Technique of Internal Fixation in various sites is discussed. This chapter should be of real value to the less experienced surgeon, as well as the two long chapters on Fractures of the Upper Extremity and Fractures of the Lower Extremity, which give definite instructions for dealing with different types of fractures.

A chapter is devoted to the account of the efforts to improve metal appliances, through the research of many individuals and committees. In 1941, the Committee on Fractures of the American College of Surgeons appointed a Sub-Committee on Screws and Plates to investigate the entire question. Following the report of this Committee, and at the suggestion of the Committee on Medical Research of the National Research Council, arrangements were made with the Metallurgical and Chemistry Departments of Columbia University to carry out experiments on the four metals which the Sub-Committee had decided met their standards of corrosion resistance, as well as of physical fitness. The tests conducted at Columbia were under the supervision of Professor Colin Fink, head of the Graduate Engineering Department; the animal experiments were carried out at the College of Physicians and Surgeons of Columbia University under the direction of the late Clay Ray Murray. The report of this Committee is included. Again and again the surgeon is cautioned that only a single metal should be used in the patient.

The progress made in the development of suitable nails, screws, and plates is most encouraging; there is need for further research.

The authors have succeeded in presenting a book of practical instructions, as well as a review of the literature dealing with the internal fixation of fractures. It will be found of special value by all surgeons who deal with fractures.

THE 1946 YEAR BOOK OF INDUSTRIAL AND ORTHOPEDIC SURGERY. Edited by Charles F. Painter, M.D. Chicago, The Year Book Publishers, Inc., 1947. $3.75.

Each year the reader of the Year Book of Industrial and Orthopedic Surgery has been impressed by the judicious choice of articles to be abstracted from the journals of the year. To bring together into so small a volume the important new developments in this field, as well as the more significant end-result studies of various conditions, requires careful reading and wise selection. The ability to choose wisely and to evaluate accurately the articles in current literature were gifts which the Editor of this volume brought to his task; they are as evident in this new volume as in those which have preceded it.

Since the Year Book of Industrial and Orthopedic Surgery was first started, in 1940, the Editor has been Dr. Charles F. Painter. His work on the 1946 volume was almost completed at the time of his death, in January 1947. It is most fitting that the publishers have dedicated this volume to Dr. Painter and have included a beautiful tribute to him, prepared by one who had long known him well, Dr. Charles H. Bradford.

The publishers announce that the new Editor of this Year Book will be Dr. Edward L. Compere of Chicago.

TRACCIÓN ESQUELÉTICA (Skeletal Traction). Carlos E. Ottolenghi. Buenos Aires, El Ateneo, 1946.

Dr. Ottolenghi has presented a thorough-going analytical review of the entire subject of skeletal traction. He states that rightfully a review of the entire body of work done by Codivilla should have been included

because he was the creator and proponent of skeletal traction as a therapeutic method. In fact, the entire first chapter is given over to the historical background of this method of treatment.

The author points out that the widespread use of this procedure has brought about results of undisputed excellence; but, as with every method of treatment, there are very precise indications and contra-indications for its use; and there is necessity for specialized instruments and a specially trained hospital staff, factors which are not always readily available.

The abuses which have been committed in the application of skeletal traction in cases where it was not indicated, and its use by others than experts, have been the causes of many failures. These failures are to be charged to errors in technique rather than to faults in principle.

However, there are real dangers inherent in the method, and these the author enumerates and describes. The two most important are infection and the possible delay of consolidation which is brought about by excessive traction. Regarding the first, if the patient is surrounded with all the necessary conditions of asepsis and antisepsis, signs of inflammation and infection should be lacking. As to delay of consolidation, the author warns against the use of excessive traction, and he emphasizes the importance of constant roentgenographic control at all times. He states as a fundamental principle the fact that in fractures, once reduction has been obtained, to continue traction for too long a time and not to permit constant contact of the end surfaces of the fragments will bring about the formation of fibrous tissue. On the other hand, the forces of concentric pressure, which act upon the focus, bring about the formation of bone callus. In other words, ideal traction avoids secondary displacement and aids consolidation.

In the course of the book, many interesting problems are referred to. In the general part, there are investigated the experimental study of the reactions of bone tissue before the application of traction; in another section the best and simplest use of skeletal traction is studied. In a special section, the particular application of the different methods of traction is taken up.

Dr. Ottolenghi has drawn from the experience of his daily work, and from the opinions of those whom he considers to be the best writers on the subject. The whole book is well documented, and there is a useful index, as well as a very complete table of contents.

Recent journals have gone more fully into the use of traction during the War, but the author indicates that he has made no effort to include such series of cases.

A Synopsis of Orthopaedic Surgery. A. David Le Vay, M.S.(Lond.), F.R.C.S.(Eng.). London, H. K. Lewis and Company Ltd., 1947. 15 shillings.

It is stated in the Preface that this volume is not intended to be other than a "factual survey of orthopaedic surgery for the use of senior undergraduates, and possibly for post-graduate students working for higher qualifications". Certain subjects, such as rheumatoid arthritis, are treated almost in outline form. The inclusion of a great deal of material in a small space, although desirable from the standpoint of completeness, does not promote clear integration or smooth reading.

A more serious defect is an occasional tendency to present only one side of a debatable question. An example is the citation of anomalous neural-arch centers as the cause of spondylolysis, the contradictory evidence not being mentioned. In a textbook for students, failure to include a bibliography is unjustifiable. With some of the clinical statistics, many readers will not agree. The Esmarch bandage is mentioned, while reference to the less injurious pneumatic tourniquet does not appear. Readers of current American literature will find it unusual to see "clinique" used for "clinical picture" or "symptoms and signs", and "tubercle" as a synonym for "tuberculosis". The author uses the older term "osteitis fibrosa" instead of "hyperparathyroidism".

The illustrations are diagrammatic line drawings, and as such are limited in value. They are clear, however; and, with rare exceptions, accurate. More illustrations might have been added, with benefit. It is unusual to find no representation of a cast, splint, or brace.

In certain departments, however, this textbook is well above the average. Brief discussions of embryology are usually informative. The author presents a modern view of low-back pain and sciatica. Avascular necrosis in general, and that of the femoral head in particular, receives deserved emphasis. The indications and technique of manipulating partially ankylosed joints are covered.

The author has succeeded in treating in a brief space the major orthopaedic disease entities, and many which are of secondary importance. He has appended a detailed and usable index.

Color Atlas of Hematology. With Brief Clinical Descriptions of Various Diseases. Roy R. Kracke, M.D. Philadelphia, J. B. Lippincott Company, 1947. $5.00.

This small atlas will fulfill a very popular demand for a concise presentation of the most important facts in hematology.

Chapters are included on the origin and development of cells, the morphology of the blood cells, and the clinical facts and blood pictures in the various blood diseases. There is a chapter on hematological technique, as well as one on the blood findings in various laboratory animals.

The blood pictures are somewhat disappointing. The purpose of such a book is to aid in identifying the different blood cells. This book falls far short of this purpose, because the nuclear details of the cells are extremely poor and erroneous. The colors are so poor that the important changes in the development of cells, as expressed by the intensity of the blue of the cytoplasm, cannot be followed.

Many of the pictures and much of the material have been reprinted from Diseases of the Blood by the same author; however, in the reproduction, much of the definition has been lost, which makes the color plates of less value than those in the original book.

PARENTERAL ALIMENTATION IN SURGERY WITH SPECIAL REFERENCE TO PROTEINS AND AMINO ACIDS. Robert Elman, M.D. New York, Paul B. Hoeber, Inc., 1947. $4.50.

The author, a pioneer and distinguished authority on the subject of the intravenous injection of proteins, has summarized the whole subject of parenteral alimentation in this fascinating monograph. He rightly ranks this procedure with anaesthetic agents and aseptic surgical technique in the advance of surgery. All of the various nutritional substances—water, electrolytes, protein, carbohydrates, fat, and vitamins—are considered, but special emphasis is placed upon protein administration, including whole blood, plasma, amino acids, and hydrolyzed protein.

Careful attention has been given to the inclusion of established facts and the exclusion of theory. Thus, the injection of potassium and magnesium solutions, still largely experimental, is barely mentioned. The practical surgeon will appreciate this critical selection. He will also approve of the detail in which the author presents his program. Thus, the question of saline versus water solutions and the relative value of the various protein mixtures are critically evaluated. A program for complete intravenous alimentation is presented, together with proof of its efficacy. A good historical summary of each topic is given, and a complete bibliography is included.

This book should be read by every practising surgeon. He will be surprised at the body of facts that the author has accumulated, and gratified by the application of these new techniques.

DIE AKTIVE BEWEGUNGSTHERAPIE. EIN LEITFADEN ZUR NACHBEHANDLUNG VON KNOCHEN- UND GELENKSVERLETZUNGEN. Dr. Rudolf Drobil. Wien, Wilhelm Maudrich, 1945. $3.00.

This book represents ten years of experience in after-treatment at the Surgical Clinic of the University of Vienna, and also the author's experience during the war years. The manuscript was finished in the summer of 1942 and was finally published in December 1944. It consists of 284 pages, printed on very good paper in simple binding.

The author divides his subject into a general part, describing the underlying principles involved in active exercise, and a second part, where these principles are applied to all the joints of the body. In his Introduction, the author states that his book has two aims: to interest more people in becoming physiotherapists and to help surgeons finish their job. He considers a surgeon's work as not finished until function has been restored, regardless of how well the injury has healed.

Active exercises are considered by Drobil to be far superior to passive motion, whether carried out by man or by machine. His physiological arguments are as follows: Any active motion is a very complex process. It starts in the brain, which sends stimuli through relays to the motor nerves and finally to the muscles. However, sensory nerves, stimulated by the mechanical irritation from moving parts, play a paramount role in the performance of a well-coordinated motion, which requires a very intricate play between stabilizing muscles, as well as between primary movers and antagonists. An impaired function means that these complicated processes, which the author compares to a chain, are interrupted in one or more places. Repair work will fail if all the members of this chain are not working properly. Thus, for instance, no passive movement will teach a patient to send stimuli from his brain through his motor nerves, unless he is encouraged to repeat the action as often as necessary until he succeeds. In other words, only active motion will restore proper function.

To avoid atrophy, it is necessary to start treatment early. At the same time, this will prevent contraction and adhesions. When normal function cannot be achieved for anatomical reasons, substitution should be attempted. In cases of stretched and weakened ligaments, increased muscle power should be developed for stabilization of the joint. A shortage of personnel often requires group treatment, which is of advantage, because competition helps the patient to overcome or to disregard his pain. The treatment should be given, however, with consideration for the individual case. Active exercise should be started after proper breathing has been accomplished. Very little equipment is necessary for this therapy,—a floor mat, a ladder, pulleys, sandbags, and different weights.

The rest of the book—by far the larger part—is devoted to a detailed description of the bony, muscular, and ligamentous parts of each joint, and their respective roles in any disability in this region. Accordingly, the exercises vary, but they always progress from a simple motion (assistance is given when necessary) to a more difficult one, performed against resistance. At the end, the exercises are done quickly, requiring considerable

muscle strength, as the muscles must then do a good deal of work. The exercises are described in great detail, so that they may be supervised even by a physiotherapist with little experience.

The book contains a number of very instructive pictures. No new ideas are expressed by the author, but it may be a handy reference book for surgeons and physiotherapists who wish to give the patient a precise program for active exercises. In general, the book seems to be an Austrian counterpart of our American reconditioning program. It is much less progressive, however, and is too much controlled by the traditional methods of after-treatment prevalent in Europe.

MUSCLE TESTING. TECHNIQUES OF MANUAL EXAMINATION. Lucille Daniels, M.A., Marian Williams, M.A., and Catherine Worthingham, M.A. Philadelphia, W. B. Saunders Company, 1946. $2.50.

This book represents an up-to-date detailed technical effort toward coordinating and simplifying muscle testing. The muscle-grading tests are arranged in systematized order for subnormal neuromuscular conditions. Although at first designed for patients suffering from acute or subacute infantile paralysis, these tests may be equally valuable in any disease or injury in which a disturbance in the neuromuscular system results in loss of muscle strength, either temporarily or permanently.

The grading and recording of muscle strength were experimented upon with various types of testing, in 1912, by Dr. R. W. Lovett. Gravity tests and prepared shaded charts for visual education were followed by the spring-balance test, devised by Dr. Lovett in collaboration with Dr. E. G. Martin. The results of measuring muscle function by the spring balance were published in 1916.

A helpful chart shows nine different methods of muscle testing which have been used by different persons or groups interested in this phase of work.

The book deals with muscle groups of defined body areas. These groups denote the origin and insertion of muscles, as well as the joint range and nerve distribution. Valuable information concerning prime movers, fixation of specific group action, and synergistic action as distinct from antagonistic action, accompany a list of valuable references. Along with charted muscle groupings are the gradings of good, fair, and poor muscle action, with line drawings to amplify the text.

This book should be of especial value to teachers of physical therapy and to students of physical medicine. It has many diagrammatic drawings and is amply illustrated.

DIE SCHEUERMANNSCHE KRANKHEIT UND IHRE DIFFERENTIALDIAGNOSE (Scheuermann's Disease and Its Differential Diagnosis). Dr. J. E. W. Brocher. Basel, Benno Schwabe & Co., 1946. 11 francs.

The first thirty-six pages of this very short monograph are devoted to a discussion of the disease, the next ten to a consideration of the differential diagnosis, and the last half of the book to the reproduction of some 122 illustrations, depicting a variety of vertebral conditions.

The author calls attention to the fact that Scheuermann's disease, first described in 1920, had been recognized by Schulthess, in 1905, as fixed round back, and later (1910) by Schanz as adolescent kyphosis or vertebral insufficiency.

In the opinion of Scheuermann and others who have studied the condition, it is to be considered as primarily a disease of overexertion. During its early phases, the symptoms consist primarily of segmental stiffness of the spine, round back, and especially of easy fatigability. Before the age of eighteen, pain is seldom noted. However, it is during the latent period that the osteo-arthrotic changes and the wedging of the vertebrae consequent upon disc damage are becoming established. After the eighteenth year, pain in the form of lumbago, sciatica, and other manifestations of low-back insufficiency become prominent.

The condition is found only in the erect human being and is apparently due to stress. As a consequence, the author insists that rest and reduction of the stress to which the back is subject, whether in play or work, should be emphasized. During the formative years, rest, proper posture, and the administration of vitamins A and D are recommended. The author believes that the use of the plaster jacket is justified only in the painful lumbar spine. For the treatment of the thoracic spine, the plaster-of-Paris corset is strictly contra-indicated, in the opinion of the author.

Although this monograph does not seem to merit the dignity of book form, the subject matter is interesting, well presented, and authoritative.

VARICES. SU TRATAMIENTO BASADO EN LA FLEBOGRAFÍA (The Use of Phlebography in the Diagnosis and Treatment of Varices). Dr. F. Martorell. Barcelona, Editorial Labor, S.A., 1946.

According to a brief introductory paragraph, Dr. Martorell first presented much of the basic material in his present book in 1940 before the Fourth National Meeting of Dermatologists. He is now setting forth the results of his own further studies in the use of phlebography in the diagnosis and treatment of varices, as well as those of several of his associates.

By way of background, the book gives in concise order a study of the etiology of varices, including a

survey of the venous system and its circulation. The problems of differential diagnosis are discussed, as well as the various methods of localizing disorders of the veins. In a third section, the previous methods of treatment, which were so often unsuccessful, are described, in order to show the evolution of the methods now being used.

This book should be of interest and value to those surgeons with a reading knowledge of Spanish.

THE HEAD, NECK AND TRUNK. MUSCLES AND MOTOR POINTS. Daniel P. Quiring, Ph.D. Philadelphia, Lea and Febiger, 1947. $2.75.

This book portrays in diagrammatic form the muscles of the head, neck, and trunk, and is intended as a companion volume to *The Extremities*, published by Quiring and his co-workers in 1945. In most instances the muscle and a brief statement of its origin, insertion, function, and the nerve and artery which supply it are included in a single diagram, based upon original dissections and upon references to Gray's *Anatomy* and Cunningham's *Text-Book of Anatomy*.

Thus this book, like the previous volume, provides a source of reference by which the anatomy of muscles may be reviewed rapidly and accurately.

THE CHALLENGE OF POLIO. THE CRUSADE AGAINST INFANTILE PARALYSIS. Roland H. Berg. New York, The Dial Press, 1946. $2.50.

The author has termed this book "the biography of a disease". It is really a report to the shareholders, the people of this country, who have contributed millions of dollars—much of it in dimes—for the care of those stricken with poliomyelitis; and, more important still, for the study of the disease,—its etiology, its method of attack, its prevention and cure. In terms for the layman, Mr. Berg makes this "report to the nation". He evaluates the results of research and states the understanding of the disease to this point.

MEDICINE IN THE CHANGING ORDER. REPORT OF THE NEW YORK ACADEMY OF MEDICINE COMMITTEE ON MEDICINE AND THE CHANGING ORDER. New York, The Commonwealth Fund, 1947. $2.00.

This book of 258 pages represents still another in the series of reports by the New York Academy of Medicine Committee on Medicine and the Changing Order. It does not pretend to answer the vital question of how more adequate medical care can be made available to more of the people; but it does attempt a survey of the present health of the nation, and an analysis of the quality and quantity of available medical services. In addition, it provides the reader with current background by its discussion of such questions as medical care in urban and rural areas, public health services, preventive medicine, hospital facilities, and so on.

As a logical development of the subject, it sums up the more important recommendations of the Committee with respect to methods for improvement of existing conditions.

When one considers that the United States, now at the very apex of its political and economic power, lags behind other nations in providing adequate medical care to all, one quickly becomes aware of the urgency of the problem, and the necessity of choosing from among the many projected solutions, the one which will bring most general satisfaction. It will be a difficult decision, for, in recent years, no other question has been the cause of such heated debate among members of the medical profession.

DIE TECHNIK DER KNOCHENBRUCHBEHANDLUNG IM FRIEDEN UND IM KRIEGE. 5 bis 8 Auflage, Band III, Die Marknagelung nach Küntscher. Dr. Lorenz Böhler. Wien, Wilhelm Maudrich, 1944. $5.25.

With each revision of Dr. Böhler's textbook on treatment of fractures, so much new material is added that the volume becomes larger and larger. This present book (the third volume of the eleventh edition) covers only one portion of the subjects treated in the previous volumes, but this portion is greatly expanded.

The larger part of the book is devoted to an exposition of medullary nailing of fractures, according to the method of Küntscher. The application of the method, with certain modifications, to the various long bones is discussed in detail and fully illustrated.

In this revision, later results in some of the 500 cases cited in earlier editions are reported. These end results, as well as nearly 100 more recent cases included in this new edition, have shown a series of unexpected late complications, such as an osteomyelitis which has become apparent as much as a year after the removal of the medullary pin, and the development of pseudarthrosis after apparent bony union has taken place.

As the result of his broader experience, the author considers the closed medullary pinning the operation of choice in simple fractures of the femur, in severely displaced simple transverse fractures of the tibia and of the humerus, and in exceptional cases of forearm-shaft fractures. He feels that open medullary nailing should be used in fresh compound fractures of the femur, but is contra-indicated in fresh fractures of the tibia and of the forearm.

The author states that, in surgical reconstruction, the open medullary nailing of the femur has definitely proved itself in old fractures, pseudarthroses, and after the shortening of wounded and of sound femora. In the reconstruction of other bones, the results of medullary nailing are, in general, more unfavorable than those obtained from employment of the earlier forms of treatment.

Intramedullary nailing has stimulated the study of callus formation; for that reason, considerable space is given to this subject in the present edition.

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Analecta Medica (México), **7**: Nos. 2 y 3, 1946.

Anales (Valencia, Spain), **1**: Núms. 1, 2, 3, y 4, 1946.

The Bethesdan (Cincinnati, Ohio), **48**: No. 1, 1947.

Boletín de la Agrupación Médica de Estudios (La Paz, Bolivia), **1**: No. 4, 1945; **2**: No. 1, 1946.

Boletín del Colegio Médico de la Habana (Cuba), **9**: Núm. 12, 1946; **10**: Núm. 1, 1947.

Boletín del Consejo Nacional de Tuberculosis (La Habana, Cuba), Dec. 1946.

Boletines de la Sociedad de Cirugía de Rosario (Argentina), **13**: Nos. 3, 4, y 6, 1946.

Brasil Médico-Cirúrgico (Rio de Janeiro), **8**: Nos. 2–4, 1946.

Bulletin of the Hospital for Joint Diseases (New York, N. Y.), **7**: Nos. 1 and 2, 1946.

The Bulletin of the U. S. Army Medical Department (Washington, D. C.), **6**: Nos. 5 and 6, 1946; **7**: Nos. 1, 2, and 6, 1947.

Child Development Abstracts and Bibliography (Washington, D. C.), **20**: Nos. 3, 4, 5, and 6, 1946.

Cleveland Clinic Quarterly (Cleveland, Ohio), **13**: No. 4, 1946; **14**: Nos. 1, 2, and 3, 1947.

Columbia University (New York, N. Y.), Bulletin of Information, Series 46, No. 35, 1946–1947.

Dolores mortales (Algias-espasmos y distrofias esplacnicas). Por el Dr. Miguel López Esnaurrízar, Mexico, D. F., 1947.

Harper Hospital Bulletin (Detroit, Michigan), **4**: Nos. 2 and 3, 1946; **5**: Nos. 1, 2, and 3, 1947.

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